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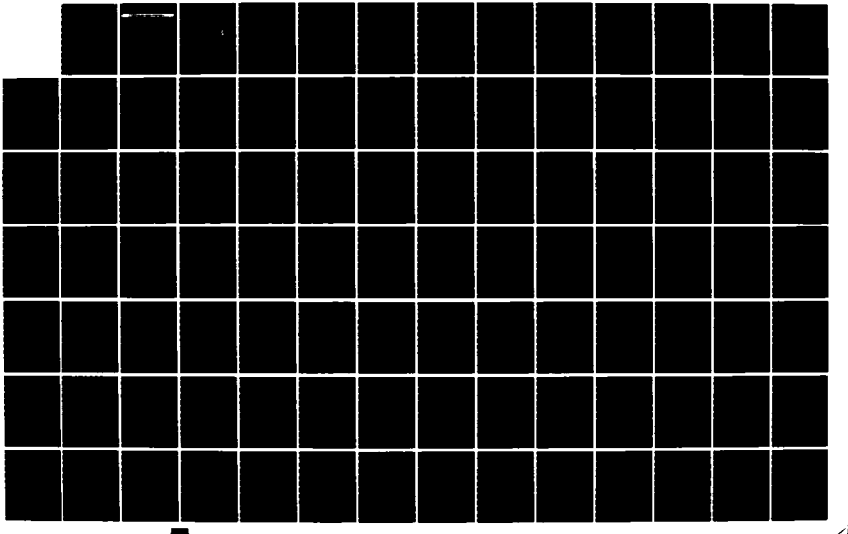

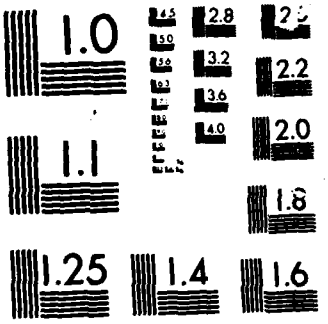

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Project 6512

30 October 1985

FORCE APPLICATION MANAGEMENT WITH AUTOPATH

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FINAL REPORT

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The Force Level Automated Planning System (FLAPS) is a computer software package developed by Systems Control Technology Inc (SCT) for the United States Air Forces in Europe (USAFE). FLAPS applies powerful mathematical optimization algorithms, detailed mathematical models, and large data base files to automatically perform critical force planning functions for tactical air assets. Program overall design is aimed towards assisting force planning personnel usually found at Allied Tactical Operations Centers (ATOC) and Allied Tactical Air Forces (ATAF) command headquarters. This report documents the proof-of-concept system that was initially delivered to USAFE and, as a demonstration system, shows how modern mathematical optimization techniques and off-the-shelf computer systems can assist force planners in quickly generating operating plans with totally effective use of limited assets.

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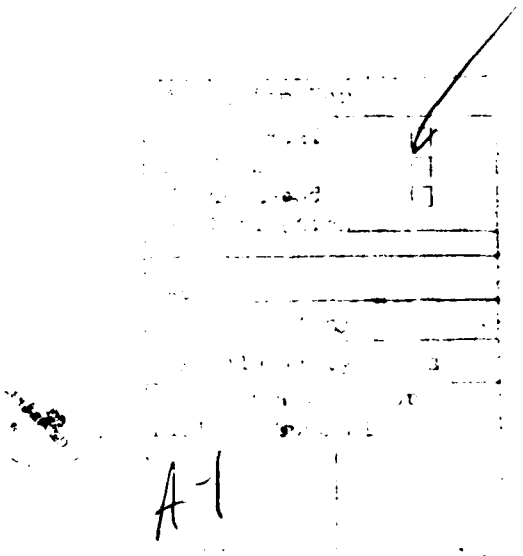

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SECTION I

INTRODUCTION AND BACKGROUND

The Force Level Automated Planning System (FLAPS) is a computer software package developed by Systems Control Technology, Inc. (SCT) for the United States Air Forces in Europe (USAFE). FLAPS applies powerful mathematical optimization algorithms, detailed mathematical models, and large data bases to automatically perform critical force planning functions. FLAPS was not designed to be used operationally. However, it is a demonstration system that shows how modern mathematical optimization techniques and computer systems can assist planners in quickly generating operating plans with totally effective use of limited assets.

FLAPS was developed under a contract with the USAFE Directorate of Operations (USAFE/DO). Under this contract, an existing SCT computer program named AUTOPATH was modified to meet the needs of USAFE. The AUTOPATH data bases were changed and expanded to support the requirements of force planners in the European central theater.

This document describes FLAPS - its performance, development, and supporting data bases.

I.1 BACKGROUND

Force planners at a NATO ATOC face a very complicated problem. The planner's overall objectives are stated in the Daily Operations Order (DOO) generated by the NATO ATAF. The planner must assign available assets to targets specified in the DOO. Ultimately, the planner will generate Air Tasking Orders (ATO's) and Air Tasking Messages (ATM's) that assign NATO attack aircraft to specific targets. ATO's and ATM's will also be issued to NATO support aircraft, i.e., particular EW support aircraft and tankers. These aircraft will be assigned to locations where they can support the penetrating attack aircraft.

Generating ATO's and ATM's is complicated by many factors. First, the aircraft available to meet the objectives of the DOO are spread out over many staging bases. Each staging base has its own inventory of aircraft and weapons. When assigning assets from a particular staging base to a specific target, the planner must insure that aircraft are available; appropriate weapons exist at the staging base; the aircraft can deliver those weapons; and the target is within range of the aircraft. These constraints must be considered within the context of the Airspace Coordination Order (ACO), which restricts the way the penetrating aircraft can fly through friendly airspace.

In addition, the enemy threat must be considered to insure the assigned missions are survivable. In the 1985-1995 timeframe, and beyond, the fixed and mobile threats will be extremely dense, rapidly changing, and lethal. These threats must be considered if the penetrating aircraft are to safely reach their targets and return.

Fortunately, current support aircraft can reduce or eliminate the threats and significantly increase the probability that the attack aircraft will safely complete their missions. The availabilty of this support will affect the assignment of attack aircraft. The attack and support aircraft must be considered simultaneously to maximize force effectiveness.

Finally, the planner is under time pressure to output the ATO's and ATM's. While data regarding the available assets and the locations of enemy threats are available, the planner may not have time to quantitatively analyze it. Without automated tools, gross approximations must be used. Errors here could adversely impact the outcome of theater tactical operations.

Many of these problems are basically numerical, and require only rapid access and correlation. For example, the status of the force (the number of aircraft and weapons available at each staging base); and performance data for attack aircraft (fuel flow, fuel capacity, etc.) are available as numerical tables. Correlating these two data bases determines if a target is within range of a particular staging base, and if the right type of weapon is available. While this is difficult and time consuming to do by hand, it is very simple to do on a computer.

This is the approach used in FLAPS. Data bases from multiple sources are integrated and data is processed in a way that systematically and quickly solves the planning problem...and optimizes force effectiveness.

I.2 BASELINE AUTOPATH

SCT's technical approach for this effort was to build a tactical force planning system for USAFE based upon an existing program called AUTOPATH. AUTOPATH is a program developed by SCT under Defense Advanced Research Projects Administration (DARPA), Strategic Air Command (SAC), and internal funding. It was developed as a research tool and contained a great deal of general capability. However, the program was not developed for tactical aircraft and their special requirements. AUTOPATH did provide a general mission planning capability based on dynamic programming and probabilistic threat modeling. This part of the program was the core upon which FLAPS was based. (Reference DARPA Seminannual Reports describing Autopath capabilities).

I.3 SCOPE AND OBJECTIVES OF THIS EFFORT

SCOPE

FLAPS is a stand-alone, proof-of-concept computer software package. The program is "stand-alone" in the sense that there are no automated interfaces with other existing computer systems or data bases. FLAPS was designed to demonstrate that powerful mathematical optimization algorithms, detailed mathematical models, and large data bases can be integrated and used to automatically perform force planning functions.

OBJECTIVE

The objective of this effort was to demonstrate that computer systems coupled with optimization techniques can assist planners in quickly generating effective plans based on limited attack and supression assets. To meet the objective, the FLAPS computer program was developed to: evaluate the feasibility of the technical approach; define operational system requirements; integrate existing government data bases; and maintain unit level compatibility.

I.4 REPORT CONTENTS

The approach taken on this project involved building on existing force planning computer software and algorithms. SCT and USAFE/DO jointly developed the requirements for a stand-alone demonstration system.

Section II describes the requirements considered during this design phase. Included are the technical modeling requirements for weaponeering and electronic combat; a description of the external data bases requiring FLAPS interface capability; the DMA and ESAMS data; and user interface requirements.

Section III describes the work done in developing the FLAPS software and data bases. This includes the key mathematical models and optimization algorithms. Also included is a description of the user interface, the data base manager, and the graphics display software.

Section IV describes the system performance of the current FLAPS software. Execution times are given for all major functions of the program.

Section V describes the computer systems considerations SCT believes are necessary to do operational force and unit level planning. These recommendations are based on SCT's experience with FLAPS and its application of PEN-AIDS to unit level planning.

Section VI describes the modifications to FLAPS that will be required to make the system operational. The most important consideration here is the requirement for a real time interface with the European Communications System.

Section VII provides a conclusion, discussion of future efforts, and appendices. Appendix A lists the formats for current FLAPS data bases. Appendix B is a comprehensive FLAPS glossary.

SECTION II

REQUIREMENTS

The first major task of the FLAPS project was to define requirements for the FLAPS computer program and the associated data bases. This task was necessary to insure that the program met the special needs of USAF force planners in the European theater. These requirements determined which specific capabilities of the existing AUTOPATH software would be used, and what new capabilities would be developed using the scope and objectives of this effort.

The requirements fell into three main areas; the data base, the user interface, and the program modifications and enhancements. They were generated based on detailed technical discussions with USAFE personnel. Each of these areas is described in the following three subsections.

II.1 DATA BASE REQUIREMENTS

SCT and USAFE personnel identified which data bases where necessary to perform force planning. These data bases are discussed in detail in Section III.1 and Appendix A.

SCT was tasked to determine which data bases currently exist and which do not. SCT found that almost all of the necessary data bases currently exist, although they are not in a format compatible with SCT's software. These data bases are given in Table 1.

Table 1. Necessary Data Bases

DMA DTED Terrain Data

Prioritized Target Data

Threat Location Data

Threat Effectiveness Data

Weapons Effectiveness Data

Force Status Data

Vehicle Performance Data

Weapons Free Zones

EC Aircraft Locations

EC Aircraft Effectiveness Data

The only critical data base that does not exist is one which defines the planner's area of interest and certain AUTOPATH program parameters. This data base is easily input by the planner, and seldom changes.

SCT also developed requirements for a data base manager which could support force level planning and operate on the above mentioned data bases. SCT determined that most of the data could be efficiently stored in a record oriented data base system. However, the several algorithms required many large array oriented data structures to store intermediate and final results. An efficient array oriented data base system was necessary for the FLAPS system to handle arrays of data like digitized terrain elevations (DTED). The arrays generated by FLAPS are discussed in Section III.1 and in APPENDIX A.

USAFE tasked SCT to determine requirements for interfacing the FLAPS program to existing data bases and systems. SCT completed this task and developed interface software for the DMA DTED and AFSA (TAC ZINGER and ESAMS) threat effectiveness data. In addition SCT developed requirements for interfacing with other critical data bases, including threat intelligence data. These requirements are discussed in Section VI.

II.2 ALGORITHM DEVELOPMENT AND MODIFICATIONS

The task of identifying the technical requirements for the FLAPS algorithms required a great deal of cooperation between SCT's technical staff and USAFE's operational personnel. While SCT's AUTOPATH program provided the basic building blocks for the FLAPS program, major modifications were needed in both the structure of the program and in the basic mathematical algorithms. In addition, new algorithms were identified to meet the special requirements of USAFE.

A large number of detailed technical requirements were generated for the FLAPS program. These requirements can be organized into the following areas:

Table 2. Technical Requirements

Threat Modeling

LLTR Routing

Staging Base / Target Accessibility

Routing and Vehicle Modeling

Weapons Allocation

Threat Suppression

The threat modeling area, required some changes from the present AUTOPATH methodology. The existing approach included a threat modeling procedure based on generic threat effectiveness data (threat templates). Given these threat templates, AUTOPATH built a lethality space (statespace), based on the position of fixed and mobile threats. Fixed threats were terrain masked. Mobile threats were considered in a probabilistic fashion which explicitly considered location uncertainty. The first priority was to acquire threat template data for all threat types and three aircraft types of interest to USAFE personnel (F-111, F-16, F-4). Second; an improved method of performing the terrain masking while saving the intermediate threat observability data was developed. This was necessary to make feasible threat suppression calculations on the statespace. Finally, an improved method of calculating mobile threat danger was required. The existing mobile threat model was prohibitively time consuming, in part due to large numbers of mobile threats in the operational area.

The requirement to support a full LLTR routing capability was identified early in the program. USAFE and NATO use LLTR points for airspace control on the friendly side of the FEBA. This is a significant constraint on the vehicle flight paths. The existing AUTOPATH program did not include an LLTR routing capability, although a general network routing capability was available.

Staging base/target accessibility refers to the rules used to determine whether a given target may be attacked by a specific staging base. Aircraft range, target characteristics, and weapons availablity are considered. Requirements for an accessibility algorithm were identified by SCT working with USAFE personnel. Accessibility considerations are consistent with the AUTOPATH approach; however, USAFE requirements dictated major changes in this area of the FLAPS program.

A key feature of the AUTOPATH program is the ability to automatically generate aircraft flight plans. This is also a key requirement for fast and effective force planning. The AUTOPATH route planning algorithm did not consider the special requirements of tactical aircraft, nor special routing constraints. Unique FLAPS routing algorithms were developed to meet these special needs. The routing algorithm was required to be completely automatic, and produce maximum survival probability routes consistent with vehicle range. Other constraints to be considered were: multiple vehicle clearance altitudes; SCL's; SCL dependent fuel capacity and fuel flow rates; turn constraints over the target; and LLTR routing constraints.

SCT developed parameters for an automatic weapons allocation algorithm based on inputs from USAFE personnel and planners. Force planning requirements dictate that this algorithm determine what type of aircraft will be tasked for each target; which staging base will be used; what weapons will be carried; and how many aircraft will be tasked. Enough weapons must be assigned to each target to reach a minimum probability of damage threshold. The weapons assignment algorithm must consider the total force of attack aircraft, and the entire prioritized target list. Aircraft must be assigned to as many targets as possible. Aircraft and weapons availability constraints must be considered as a central part of the weapons assignment.

The FLAPS program must assist the force planners in coordinating attack and EC aircraft. In the European theater, EC aircraft will be used to open high probability of survival corridors. The FLAPS planning software must be consistent with this doctrine. Thus, the FLAPS program was required to assist the planner with the following: deciding where corridors should be placed; selecting different possible corridor locations; modeling in detail the effectiveness of EC aircraft against the threats adjacent to the corridors; and

producing attack aircraft flight plans that take advantage of the corridors. Three types of EC aircraft must be considered - the EF-111, the EC-130H (Compass Call), and F-4G and F-5E (Wild Weasel). The model must correlate the effectiveness of a variety of EC aircraft against a diversity of threats.

Finally, the FLAPS program was required to provide a framework that will allow the models to work together in a fast and effective manner. Intermediate results, detailed reports, and color graphics were needed to show the planner what is happening at each step of the planning process.

II.3 USER INTERFACE AND GRAPHICS DISPLAYS

SCT and USAFE personnel determined requirements for the FLAPS user interface and graphics display system. The resultant interface is discussed in Section III.5. The preliminary FLAPS system is a prototype and is not meant to be an operational system. However, the program must be as easy to use as possible. The requirement was to design a user interface which minimized the number of required keystrokes, yet maintained flexibility in using the program. A detailed on-line help feature was also needed, along with a type ahead feature to accommodate expert users.

The force planner must monitor a great deal of complex information in order to produce effective plans. This prompted development of a color graphics display system. It would clearly display all critical planning data, while allowing user inputs through the graphics display. The graphics display system is discussed in Section III.6.

SECTION III

PROGRAM MODIFICATIONS

Major modifications were made to the AUTOPATH program to meet USAFE force planning requirements. These changes affected all aspects of the program; only the basic underlying mathematical algorithms were unaffected. The result is the FLAPS program. The program modifications and enhancements are described below.

The AUTOPATH program provided powerful mathematical algorithms for use by both strategic and tactical mission planners. However, the progam was not tailored to meet the specific needs of USAFE force planners. Early in the FLAPS program design effort, a solution approach for tactical force planning was identified. This approach is referred to as the "Six Step Planning Approach" and it guided the development of the FLAPS program. When this approach was understood, it allowed modification of the basic AUTOPATH models and algorithms to meet the specific requirements of USAFE. The six steps are listed in Table 3.

Table 3. Six Step Plans Approach

STEP 1	UPDATE THE DATA BASE.
STEP 2	DETERMINE STAGING BASE AND TARGET ACCESSIBILITY.
STEP 3	COMPUTE OPTIMAL INGRESS AND EGRESS ROUTES TO TARGETS.
STEP 4	ALLOCATE WEAPONS TO TARGETS.
STEP 5	ALLOCATE SUPPORT AIRCRAFT TO OPEN HIGH PROBABILITY OF SURVIVAL FLIGHT CORRIDORS.
	(steps 3, 4, and 5 may be iterated)
STEP 6	OUTPUT ATO's.

STEP 1 is to update the force status data, the current target list, the Airspace Coordination Order (ACO), and the current threat status. Force status, target, and ACO data is stored in the FLAPS data base and is used continuously in the remaining five steps. The threat data is processed into the large lethality or "statespace" array. This array is a summary of the entire enemy threat laydown. Figures 1 through 3 are graphic representations of various aspects of the data base.

STEP 2 is to search the prioritized target list to determine staging bases within range of each target with weapons effective against that target. Staging bases within range and with appropriate weapons are said to be "accessible." Force status data is part of the accessibility calculations. This data includes current inventories of aircraft and weapons at each staging base.

Figure 1. Bases, LLTRs, ROZs, WFZs, and Targets

Figure 2. Addition of Threats

Figure 3. Danger Contours (Terrain Masking)

Once the data bases (including the statespace) have been calculated and accessibility has been determined, the "optimal" ingress and egress flight paths are computed. This is STEP 3. Optimal routes are generated for every target from each accessible staging base. Performance data is calculated for each route. This data includes the probability of survival and the number of aircraft required to attack the target to reach the minimum damage threshold. This data is then stored in the data base.

Using accessibility and route performance data, FLAPS determines which staging bases should be matched with each target. This is the weapons allocation step, STEP 4. In general, several staging bases may be within range of a given target. FLAPS searches the route performance data for each of these staging bases and determines which staging base is most appropriate. This staging base is then assigned to the target. This is done for each target, in order of priority, until either the supply of weapons or aircraft is exhausted.

Optimal routes are generated using the statespace with a very fast and efficient dynamic programming algorithm (DPA). Routes are optimal in the sense that no other path between the staging base and the target will have a higher probability of survival. The ability to quickly generate optimal flight plans, and change the lethality of the enemy threat laydown (change the statespace), gives FLAPS its power.

Up to this point, no electronic combat (EC) suppression has been applied, so the penetrating fighters may encounter significant threat danger. The initial set of routes is available to assist the planner in deciding where to put the available EC suppression assets. In Step 5, the planner applies the EC suppression assets using a color graphics terminal. Graphic displays and reports help the planner determine where EC suppression is required and where it will be most effective. After the planner determines EC suppression application points, FLAPS updates the statespace to reflect the effects of EC suppression.

Then the optimal flight paths are recalculated. Typically, the routes will change in priority to reflect the "high probability of survival corridors" through the FEBA opened by the EC suppression assets. Again reports and graphic displays show the planner how effective this allocation will be for improving survival probability of the penetrating fighters. The planner may try several types of EC suppression allocations. Step 6 involves generating the ATO which gives the best allocation of weapons to targets, and locations for the EC suppression assets. (The current FLAPS does not output this data in a NATO standard ATO format.)

This six step process describes the overall structure of the FLAPS program and its use. Descriptions of the underlying models are described in Table 4.

Table 4. Subsection Outline

Subsection III.1	Data Base Manager Data Bases, Programs Interfacing with FLAPS Data Bases
Subsection III.2	LLTR Selection Algorithm
Subsection III.3	Weapons Allocation Algortihm
Subsection III.4	Threat Suppression Models
Subsection III.5	User Interface
Subsection III.6	FLAPS Graphic Display System

III.1 DATA BASE MANAGER, DATA BASES, AND DATA BASE INTERFACES

A large amount of data is needed to drive the FLAPS program. To effectively handle large, complicated data bases, SCT used a previously developed data base manager. Working with USAFE personnel, SCT acquired the relevant data and constructed a base line data base. An unclassified test scenario was established and was used for testing, training, and demonstrations. In some cases, necessary data already existed in U.S. government data bases. However, the format of this data was not directly usable by the FLAPS data base manager. These cases led to development of special data base interface programs. Specifically, a special program was written to interface DMA DTED data with FLAPS. A program to accept threat lethality data from government sources was created as well.

III.1.1 The FLAPS Data Base Manager

An effective force planning system requires a specialized data base management system (DBMS). This DBMS must have data handling algorithms to efficiently accommodate two basic types of data, record-oriented data and large matrices. Such a data base manager was developed for other automated mission planning applications and integrated with FLAPS. Record-oriented data is handled in data base "tables" and large matrix type data is handled in data base "arrays." The fact that both types of data are handled efficiently is critical to the success of the FLAPS program.

As a general rule, the user interfaces with the data bases through the data base tables. The user can easily make changes, additions, or deletions to the tables. The user may access an individual record from each table. For example, the TG (target) table will contain a record for each target of interest to the planner. This table should correspond to the current prioritized target list.

Many tables are static. They are used by the program to describe fixed vehicle and subsystem models, and to control the data bases and graphics display terminal. These tables are transparent to the user.

The FLAPS program automatically generates arrays while performing the threat lethality computations, route generation, and target allocation functions. The user cannot directly change the information in arrays. However, the FLAPS program automatically updates the arrays as necessary when the tables are changed. One special array is the BYTE (byte packed terrain data) array. This array contains the DMA DTED data stored in a special byte packed format. This array is not generated by the program and must be input into the system. This BYTE array is discussed further in Subsection III.1.3.

III.1.2 The FLAPS Data Base

To use the FLAPS program, the user is responsible for data input which describes the current wartime situation. Currently there are no automated interfaces between FLAPS and other computer systems or data bases. (See Appendix A for FLAPS data base specification.)

The data base is divided into two parts - the tables and the arrays. Much of the data base is static and will not change as the wartime situation changes. This includes the DMA DTED terrain data and certain tables which are used internally by the FLAPS program to control the data base and graphics display terminal. Many tables (and all but one array) are generated automatically by the program and require no user inputs. The data base tables are the primary vehicles for access to the data base.

A brief summary of the data base tables is given in Table 5. An asterisk next to a table name indicates a table which will probably be frequently updated by the user. (See Appendix A for detailed data base description.)

Table 5. FLAPS Data Base Tables

ALGP		Algorithm Parameters. This table defines the dimensions of the lethality space and other data related to the dynamic programming algorithm and aircraft routing.
ASTR		Array Structure. Initialization data for the array data bases.
CURR		Current Processing Status. This table keeps track of which algorithms need to be executed in response to user input data base changes.
DISP		Display Parameters. Data related to device dependent graphics displays.
GEOM		Geometry Coordinate Tranformations. Data related to the coordinates of the scenario and lethality space.
LLTR	*	LLTR Locations. This user input table defines the positions of the Low Level Transit Routes.
NODP		Node Parameters. Data related to the numbers of staging bases, targets, and LLTR points.
PBOR		Political Borders. Coordinates of the political borders for the European theater.
ROZ		Restricted Operating Zones. Coordinates of current restricted operating zones.
SPED		Sortie Records. Table containing sortie information, including waypoints and survivability data.
STCH	*	Stochastic Threat Locations. Positions of imprecisely located threats.
STGB	*	Staging Bases. This table contains the locations and available assets for each staging base of interest in the scenario.
SUPM		Suppressor Model Parameters. Effectiveness data for the EC aircraft.
SUPP	*	Suppressor Positions. Positions for the EC aircraft during the current planning cycle. This data is normally input graphically by the user.

SWCH		Software Switches. Data related to fidelity of the terrain masking algorithm and other models.
TG	*	Target Positions. This table contains the prioritized target list. Target location, type, and minimum acceptable probability of kill are included.
THRT	*	Threat Positions. This table contains data on threats with known locations. Threat location, type, and time entered into the system are included.
TMDL		Threat Models. Effectiveness data on each threat type is contained in this table.
TSTR		Table Structure. Static data which supports the table data base manager.
VEHP		Vehicle Performance Parameters. This table contains vehicle performance data for the attack aircraft; includes fuel capacity and SCL dependent fuel flow rates.
WEAP		Weapons Effectiveness Parameters. Data relating the effectiveness of each type of weapon to each type of target.
WFZ		Weapons Free Zones. Locations of the theater dependent weapons free zones.

The data base arrays are listed in Table 6 along with a brief description. Recall that the BYTE array must be input into the program. All other arrays are automatically generated by the FLAPS program.

Table 6. FLAPS Data Base Arrays

NAME	DESCRIPTION
ALTG	ARRAY OF OPTIMAL CLEARANCE ALTITUDES (NOT CURRENTLY USED)
ALTS	ARRAY OF TERRAIN ALTITUDES ABOVE SEA LEVEL (NOT CURRENTLY USED)
ARCS	WAYPOINTS FOR THE OPTIMAL INGRESS AND EGRESS ARCS
ARPE	PERFORMANCE DATA (PS AND DISTANCE) FOR THE INGRESS/EGRESS ARCS
BYTE	THE BYTE PACKED DMA DTED TERRAIN DATA (USER SUPPLIED)
CL3D	THREE-DIMENSIONAL CLOBBER STATESPACE (NOT CURRENTLY USED)
ITGC	ARRAY CONTAINING TARGET AND STAGING BASE ACCESSIBILITY DATA
ITRC	ARRAY CONTAINING EFFICIENT LLTR TREES
MASK	ARRAY CONTAINING TEMPORARY TERRAIN MASKING DATA
NBOX	WINDOWS INTO THE STATESPACE (USED TO COMPUTE ARCS)
NLIS	MASTER LIST OF NODES (STAGING BASES, LLTR'S, AND TARGETS)
NPOS	LIST OF NODE POSITIONS (LONGITUDE AND LATITUDE)
ROUT	ROUTE PERFORMANCE (PS AND DISTANCE)
STAT	THE TWO-DIMENSIONAL STATESPACE
SXPE	PERFORMANCE DATA FOR THE EFFICIENT LLTR TREES
TGUS	TARGET STATUS ARRAY (EFFECTIVENESS OF THE WEAPONS ALLOCATION)
TH2D	TWO-DIMENSIONAL THREAT DANGER (NOT CURRENTLY USED)
TH3D	THREE-DIMENSIONAL THREAT DANGER (NOT CURRENTLY USED)
TOBS	THREAT OBSERVABILITY DATA (TERRAIN MASKING DATA)
TRPE	INTERMEDIATE LLTR TREE DATA

III.2 LOW LEVEL TRANSIT ROUTE (LLTR) SELECTION

SCT modified the AUTOPATH software to support the requirement for LLTR routing. An LLTR is a "safe" path used by friendly aircraft. It determines the

flight path of a sortie from a staging base to the FEBA. Later in the mission, the sortie will use an LLTR to return to the staging base from the FEBA.

An LLTR is comprised of one or more Low Level Transit Segments pieced together. A Low Level Transit Segment is a great circle line formed by two Low Level Transit Nodes. Low Level Transit Nodes are navigation points which have been selected because of their ease of identification.

At any given time, some of the Low Level Transit Segments are active while the rest are inactive. Aircraft flying in a straight line between the two Low Level Transit Nodes of an active segment will be considered friendly by ground forces and not fired upon. Aircraft not on active segments will be considered hostile.

Whether a Low Level Transit Segment is active or inactive is dictated by the daily Airspace Coordination Order (ACO). LLTR data from the ACO is input to FLAPS through the LLTR table. Currently there is no automated interface between the ACO and FLAPS, so the user must update the LLTR table. The user specifies which nodes are inactive; which nodes can be used to enter the LLTR network (designated either as entry or exit points); and which nodes are active intermediate nodes (i.e. nodes which are active but neither entry nor exit nodes). The connectivity of the network must be specified by listing every active node that can be reached from each active node. Figure 4 depicts an LLTR network representative of FLAPS processing.

Once the Low Level Transit network has been defined, FLAPS finds the set of optimal LLTRs. This route selection is accomplished by the application of a Dijkstra Shortest Path algorithm. For each LLTR entry node, the algorithm finds the shortest path through the LLTR network to each accessible LLTR exit node. Note that not every LLTR entry node is connected through the network to every

Figure 4. LLTR Network

LLTR exit node. Looking at the connectivity of the network, accessibility is easily determined. Performance (distance and probability of arrival) on these paths is stored in the TRPE array. The actual sequence of segments making up a path is stored in the ITRC array.

Since LLTR entry nodes are located near staging bases and LLTR exit nodes are located near the FEBA, an out-bound sortie would fly through the LLTR network by entering the network at an entry node and leaving the network at an exit node. The sortie would return to the staging base by entering the LLTR network at an exit node and leaving the network at an entry node. The same entry and exit points may be used for ingress and egress. However, the ingress path may be different from the egress path. The actual paths are chosen in a manner that maximizes probability of survival of the sortie - subject to all mission constraints. Figure 5 graphically depicts optimal routes to LLTR exit nodes.

After the LLTR route segments have been processed, the target/staging base accessibility algorithm is executed. This is accomplished by looking at which staging bases are within range of each target. Route distance is approximated at this point. Distance through the LLTR network (which is known at this time) is considered. However, because the optimal paths between the LLTR exit points and the targets have not been calculated yet, great circle distance between the LLTR exit points and the targets is used. A 15% factor is added to this great circle distance to approximate the increased distance generated by maneuvers to avoid these threats.

Figure 5. Optimal Routes to LLTR Exit Nodes

In addition to range factors, weaponeering is considered in the accessibility algorithm. Only staging bases with weapons and aircraft in sufficient numbers to be effective against a target are considered.

III.3 ATTACK AIRCRAFT ROUTING

SCT modified the AUTOPATH aircraft routing algorithm in order to meet USAFE specifications. The FLAPS routing algorithm creates and evaluates candidate sorties to each target from each accessible staging base. Every sortie consists of a target; staging base; round trip route from target to staging base; number and type aircraft and weapons.

Round trip routes are assembled from the optimal route segments generated by the Dijkstra and Dynamic Programming algorithms. Aircraft type is specified for the staging base in the table STGB. A weapons effectiveness table, resembling a condensed version of the Joint Munitions Effectiveness Manual (JMEM), is used to compute the number of each weapon type required to successfully attack the target. The weapon carrying capacity of the aircraft then determines the number of aircraft required.

Often, many combinations of routes and weapon types are possible for a given target/staging base pair. The FLAPS routing algorithm evaluates these combinations against an aircraft fuel model which recognizes the dependence of fuel flow and fuel capacity on the weapon package carried. Those combinations which are consistent with this fuel model are considered feasible sorties. Each feasible sortie has several parameters which describe its quality:

N = The number of attack aircraft

PS = The round trip probability of survival

D1 = The route distance (NM) through the friendly side of the FEBA

D2 = The route distance (NM) through the enemy side of the FEBA.

The derived quantity :

$$Q = N * (1-PS + C1*D1 + C2*D2)$$

is small for a sortie with a small number of aircraft flying a short, safe route. Conversely, Q is large for a sortie with a large number of aircraft flying a long, dangerous route. Thus, Q is regarded as a "cost" associated with the sortie. For each target/staging base pair, the FLAPS routing algorithm selects the feasible sortie with minimum Q value and stores a summary of it in the ROUT array. The coefficients C1 and C2 appearing in the definition of Q are presently set at 0.0001 and 0.0003 respectively. Thus, the routing algorithm will sacrifice 0.01 in PS, if it can decrease D1 by 100 NM or D2 by 33.3 NM. Figure 6 shows optimal ingress and egress flight paths from a specified target to all LLTR exit nodes.

III.4 WEAPONS ALLOCATION

The FLAPS allocation algorithm determines the assignment of sorties to targets and stores these assignments in an array (Array TGUS) resembling an Air Tasking Order. This allocation process is driven by the prioritized target list given in the Daily Operations Order. It is constrained by the weapon and aircraft inventories specified for each staging base.

The algorithm considers the targets in order of decreasing priority. Using the routing algorithm, each target is assigned the "safest" sorties assembled from the inventories of remaining aircraft. The safety criterion used in this selection is based on two quantities associated with each sortie :

N = The number of attack aircraft

Figure 6. Optimal Ingress/Egress Flight Paths

PS = The round trip probability of survival.

The derived quantity :

$$R = N * (1-PS)$$

defines, in a probabilistic sense, the expected number of aircraft lost on the sortie. Therefore, R represents the total risk associated with the sortie. The safest sortie is defined as the one with the minimum value of R. Thus, the algorithm will select a sortie with N = 2 and PS = 0.85 over one with N = 4 and PS = 0.9 since

$$2*(1-0.85) < 4*(1-0.9) .$$

When aircraft inventories are low, some targets near the bottom of the list cannot be successfully attacked with the available aircraft. The present algorithm makes a single pass through the target list - no attempt is made to attack low priority targets at the expense of the safety of the sorties assigned to higher priority targets.

III.5 THREAT SUPPRESSION

SCT implemented a method to quickly evaluate the effects of EC aircraft on a given threat laydown. This permits the FLAPS user to quantitatively measure EC aircraft effectiveness and plan EC aircraft deployments based on these results.

FLAPS currently handles three different types of EC aircraft: EC-130H's (Compass Call), EF-111's, and F-4 Wild Weasels. Each aircraft degrades the threat in a different way. EC-130s disrupt enemy communications links, EF-111's jam enemy acquisition radars, and Wild Weasels use HARM radiation seeking

missiles to destroy enemy SAM systems. FLAPS maintains a seperate threat suppression model for each of these EC aircraft. A model contains information on suppressor effectiveness against every type of enemy threat system.

The FLAPS threat suppression model was developed as an extension to the existing AUTOPATH threat modeling approach. Generic threat effectiveness data is stored in the threat model (TMDL) table. A threat model (template) exists for each threat and aircraft type. For example, a single threat template might contain effectiveness data for an SA-6 against an F-16. Threat effectiveness is specified as the negative log of the probability of survival per second at each up-range/down-range and cross-range position within the threat's radius. Currently, both classified and unclassified threat models exist. The classified models are derived from TAC ZINGER outputs supplied by the Survivability/Vulnerability Information Analysis Center (SURVIAC).

Information about specific threat locations is contained in the threat location (THRT) and stochastic threat location (STCH) tables. The THRT table contains location and threat type data for every threat with a known position. The STCH table contains information about mobile threats whose locations are not precisely known. The threats with known locations are terrain masked using DMA DTED terrain data. For each of these threats, danger (from the threat model table) is added to all statespace cells which are within the radius of the threat and which are not terrain masked. The terrain masking data is stored on disk for later reference. For the mobile (or stochastic) threats, a special mobile threat model is applied which spreads the threat danger out over the area where the mobile threat is believed to be operating. This danger is also added to the statespace.

The lethality space then contains all of the information about the threat laydown. The dynamic programming algorithm may be run at this time and the result will be the optimal ingress and egress routes between all accessible targets and staging bases. However, the probabilities of survival at this stage could be very low - threat suppression has not been applied.

Threat suppression is accomplished by rapidly adjusting the lethality space to reflect the reduced threat effectiveness caused by the EC aircraft. (At this point the user may re-optimize all routes.) The user inputs the locations of the EC aircraft (orbit points) using the graphic display terminal. The suppressor positions are stored in the suppressor position table (SUPP). The graphic display makes it easy for the user to quickly determine the geographic areas that would benefit most by the application of threat suppression assets. Figure 7 shows the FLAPS depiction of EC aircraft suppression coverage areas. Once these areas are isolated, the user can specify the asset type and position it by moving the graphics cursor to the the desired position using a joystick. This action will create a circle on the screen, centered at the suppressor position. The circle's radius equals the range of the specified suppressor type. The user may repeat this process until the suppressor assets have been deployed.

Figure 7. EC Aircraft Locations

Another FLAPS feature that helps a user position threat suppression assets is the ANALYZE command (see Figure 8). This permits the user to analyze a route to determine which route legs and threats are the most dangerous. Displaying threats producing the most hazard allows quick selection of candidate areas for suppressor deployment.

ANALIZ-- NUMBER OF CRITICAL POINTS: 41
NUMBER OF THREATS : 97
ALTITUDE OF ROUTE : 60.10
TOTAL PROB OF SURVIVAL : 0.074993
TOTAL DISTANCE OF ROUTE : 1138.7262

INDEX	TIME (MIN)	LATITUDE (DMS)	LONGITUDE (DMS)	HEADING (DEG)	ALT (FT)	LEG PS	NODE NAME
1	0.0	52 24 00	0 34 60	115.75	197	1.000	LAKENHTH
2	33.2	50 26 54	6 56 16	89.73	197	0.990	N001
3	35.6	50 26 59	7 26 33	46.31	197	0.999	N002
4	39.2	50 46 50	7 59 24	56.62	197	0.999	N003
5	42.6	51 01 47	8 35 29	72.33	197	0.999	N004
6	46.5	51 11 12	9 22 43	133.05	197	0.999	N005
7	50.0	50 52 30	9 54 27	62.99	197	0.887	WAYPOINT
8	50.6	50 54 60	10 02 14	90.00	197	0.877	WAYPOINT
9	55.9	50 54 60	11 08 21	135.53	197	0.358	WAYPOINT
10	56.3	50 52 30	11 12 14	90.00	197	0.995	WAYPOINT
11	56.6	50 52 30	11 16 08	135.50	197	0.999	WAYPOINT
12	57.1	50 49 60	11 20 01	98.88	197	1.000	WAYPOINT
13	61.1	50 45 00	12 10 35	90.00	197	0.999	WAYPOINT
14	64.2	50 45 00	12 49 28	108.69	197	0.997	WAYPOINT
15	65.2	50 42 30	13 01 08	135.38	197	0.997	WAYPOINT
16	66.1	50 37 30	13 08 55	90.00	197	1.000	WAYPOINT
17	67.6	50 37 30	13 28 22	136.35	197	1.000	WAYPOINT
18	70.8	50 19 00	13 55 60	124.02	197	0.985	PANENSKY
19	71.1	50 17 30	13 59 29	44.80	197	0.989	WAYPOINT
20	71.6	50 19 60	14 03 22	315.38	197	1.000	WAYPOINT
21	74.7	50 37 30	13 36 08	270.00	197	0.999	WAYPOINT
22	76.8	50 37 30	13 08 55	315.43	197	0.999	WAYPOINT
23	77.7	50 42 30	13 01 08	288.71	197	1.000	WAYPOINT
24	78.7	50 45 00	12 49 28	270.00	197	0.997	WAYPOINT
25	80.8	50 45 00	12 22 15	315.48	197	0.998	WAYPOINT
26	81.3	50 47 30	12 18 21	270.00	197	0.999	WAYPOINT
27	83.4	50 47 30	11 51 08	277.25	197	0.997	WAYPOINT
28	85.9	50 49 60	11 20 01	315.53	197	0.999	WAYPOINT
29	86.4	50 52 30	11 16 08	270.00	197	1.000	WAYPOINT
30	86.7	50 52 30	11 12 14	315.55	197	0.999	WAYPOINT
31	87.1	50 54 60	11 08 21	270.00	197	0.995	WAYPOINT
32	90.5	50 54 60	10 25 34	315.61	197	0.695	WAYPOINT
33	91.4	51 00 00	10 17 47	270.00	197	0.807	WAYPOINT
34	93.8	51 00 00	9 46 40	304.30	197	0.537	WAYPOINT
35	94.9	51 04 60	9 35 00	308.86	197	0.976	WAYPOINT
36	96.2	51 11 12	9 22 43	252.39	197	1.000	N005
37	100.1	51 01 47	8 35 29	236.77	197	0.999	N004
38	103.5	50 46 50	7 59 24	226.51	197	0.999	N003
39	107.1	50 26 59	7 26 33	269.73	197	0.999	N002
40	109.5	50 26 54	6 56 16	296.72	197	0.999	N001
41	142.7	52 24 00	0 34 60	296.72	197	0.990	LAKENHTH

Figure 8. Sample ANALYZE Command Output

Once the suppressors have been deployed, it is necessary to calculate their effect on the statespace. For every asset in the Suppressor Position table, the Suppressor Model table is consulted to determine its effectiveness against all threats within its range. Each threat affected is removed from the statespace, then its degraded threat is added back in. For fixed threats, this can be done quickly. Since FLAPS stores all of the terrain masking data associated with a threat, it avoids recomputing this information. For mobile threats, the suppressor model reacts quickly as well. The mobile threat modeling approach was designed to be compatible with the FLAPS threat suppression models.

Each type of threat suppressor has an associated capacity. If the suppressor is positioned with more threats in its range than it can handle, then its effectiveness is reduced by an amount proportional to the excess number of threats. Therefore, a suppressor with a capacity of five threats, when placed within range of ten threats, will be only one half as effective (on a per threat basis). However, the effects of the suppressor will be spread out over all ten threats.

After altering the statespace for suppression effects, the dynamic programming algorithm is re-run to find the optimal paths. This done, FLAPS re-allocates the sorties to find the best mission assignmnent given the new threat laydown. If the user is still not satisfied with the allocation, it is a simple matter to quickly re-position the suppressors and attempt to improve the results. Figures 9 and 10 represent graphic displays before and after suppression. Routing and allocation change as a result.

III.6 USER INTERFACE

SCT made substantial changes to the AUTOPATH user interface for USAFE

Figure 9. Lethality Space and Routing - Before Suppression

Figure 10. Lethality Space and Routing - After Suppression

personnel. These changes are summarized:

Tailor the user interface for force level planning

Reduce the number of keystrokes; use two stroke COMMONS

Provide extensive on-line help

Allow user interaction with the graphic displays

Both the AUTOPATH and FLAPS programs are command driven. If the user has a question about which command is needed during a run, he may type HELP. The primary commands (used most often by a planner) are listed in Table 7.

Table 7. FLAPS Primary Command

FLAPS PRIMARY COMMANDS

CONTROL COMMANDS:

HE	OBTAIN HELP
RE	READ COMMANDS FROM A FILE
QU	QUIT FLAPS EXECUTION

DATA BASE COMMANDS:

AD	ADD A RECORD TO THE DATA BASE
DE	DELETE A RECORD FROM THE DATA BASE
CH	CHANGE A RECORD IN THE DATA BASE
SH	SHOW CONTENTS OR STRUCTURE OF D.B.

ALGORITHMS AND DISPLAY:

PR	PROCESS ALL ALGORITHMS
DI	PRODUCE A GRAPHICAL DISPLAY
FI	FIND AN OBJECT GRAPHICALLY

SUPPRESSION COMMANDS:

SE	SELECT ROUTE
AN	ANALYZE ROUTE
LO	LOCATE SUPPRESSOR
SU	APPLY SUPPRESSION
RR	RE-CALCULATE ROUTE WITH SUPPRESSION
RS	RESTORE ENVIRONMENT W/O SUPPRESSORS

Many of the primary commands require additional information. The user is automatically prompted for this information after entering the primary command. All FLAPS commands and subcommands require only two keystrokes. Expert users are accommodated by the user interface with a type ahead feature. Suboptions and data may be entered on the same input line as the primary command; intermediate prompts are not issued by the program. A number of secondary commands are available for program developers.

The user may obtain help at any time during program execution simply by typing "HE" (i.e. "HELP"). The user may obtain a full description of every entry he must make by putting FLAPS in a "HELP ON" mode. Under this mode, help is constantly provided for every input.

FLAPS allows the user to search the data base, input suppressor, ROZ, and WFZ positions; and input/modify routes directly through the Tektronix 4115B color graphics terminal. This feature is very convenient because FLAPS provides most planning information to the user graphically.

III.7 DISPLAYS

The AUTOPATH graphic displays have been substantially modified for the FLAPS program. FLAPS has been designed to provide force planners with a wide variety of high resolution color graphic displays. By permitting the user to quickly and easily specify and display any combination of graphic options, FLAPS enables the user to readily assimilate large amounts of data encountered when planning at the force level.

Great care has been taken to maximize the utility of the FLAPS graphic displays. This goal was met by making the selection of display options user friendly. Every effort was made to minimize the number of keystrokes needed to call up a specific display. All display options require typing at most two characters for selection. The characters were carefully selected to provide meaningful mnemonics. Figure 11 is the display prompt in FLAPS with the help turned on.

```
 ENTER "SC" TO SCALE PLOTTING WINDOW
   B    OR  "/"  TO DRAW GRAPH
   OR NEXT SYMBOL TO TURN ON AN OPTION
   OR SYMBOL FOLLOWED BY "-" TO TURN OFF OPTION
   OR  "P"  TO TURN OFF ALL OPTIONS
 SYMBOL  STATUS    DEFINITION
-----------------------------------------------
  A               ALTITUDE CONTOURS
  AR              ARCS
  B               BOUNDARY OF GPHC WINDOW
  C               THREAT CIRCLES
  D               DANGER CONTOURS
  E               ENVELOPES
  G               GRID LINES
  I               INDEXES                 (option not supported)
  L               LONGITUDE/LATITUDE
  LL              LLTRS
  M               MISSION (BDRY + NODES)
  MA              MASKING                 (option not supported)
  RO              ROUTES
  RZ              ROZS
  ST              STAGING BASES
  SU              SUPPRESSION CIRCLES
  TG              TARGETS
  V               CONTROL VECTORS         (option not supported)
  WF              WFZS

CHOOSE OPTIONS or Scale:
```

Figure 11. FLAPS Help Display - Prompts

Note that these are only the major display options. Selecting many of the options would prompt the user with lists of suboptions. For example, after selecting "C" for threat circles, the user would receive a prompt identifying all of the active threat types available for display. The user could then specify display of all threat circles, or any combination of threat circles.

Any time the user instructs FLAPS to draw a graph, all selected options will be drawn. The user can cancel a specific option by entering the option prefaced by a minus sign (before giving the draw graph command). To purge the list of selected options, the user enters a "P" before specifying the new list of display options. Table 8 is a summary of the major FLAPS graphic display options.

Table 8. FLAPS Graphic Display Options

ALTITUDE CONTOURS: Displays a topographic map of the terrain. The user specifies the MSL altitudes desired for viewing.

ARCS: Displays either the set of optimal paths from a staging base to all accessible LLTR exits or the set of optimal paths from a target to all of its accessible LLTR exits.

BOUNDARY OF GRPHC WINDOW: Displays the box around the scenario and all of the political borders in the scenario.

THREAT CIRCLES: Displays the envelopes of all fixed threats of the selected type or types.

DANGER CONTOURS: Similar to terrain contours, however they show lines of constant danger (probability of kill per second) for a given direction. These are the best way for the user to visualize the total threat laydown.

ENVELOPES: Displays the boundaries of extent for any or all of the stochastic threat types in the statespace.

GRID LINES: Displays the actual cell boundaries used by the dynamic programming algorithm.

LONGITUDE/LATITUDE: Displays a labeled grid of longitude and latitude lines.

LLTRS: Displays all active LLTR nodes in the scenario.

MISSION: Displays all active nodes (staging bases, LLTRs and targets) as well as the political and statespace boundaries. This is a short cut to avoid having to specify all of these frequently desired options individually.

ROUTES: Displays any specific route or set of routes stored in the SPED file.

ROZS: Displays all Restricted Operating Zones in the scenario.

STAGING BASES: Displays all staging bases in the scenario.

SUPPRESSION CIRCLES: Displays circles centered where each suppressor is positioned. Each circle has a radius equal to the range of the suppressor type at that position. The user can specify which suppressor types to display.

TARGETS: Displays all active targets in the scenario.

WFZS: Displays all of the active Weapons Free Zones in the scenario.

The Tektronix 4115B terminal supports a hardware zoom feature which allows users to zoom in on parts of the scenario. In addition to this feature, FLAPS allows the user to rescale the display (the "SC" option) to enlarge part of the scenario. The user may rescale to the entire scenario (the "SC" suboption), zoom in on the statespace (the "ST" suboption), or input the longitude/latitude coordinates of his desired window. FLAPS also displays a legend to help the user interpret the display.

There are many FLAPS commands that can be performed by interacting directly with the graphics display. The user can position threat suppression assets by moving the graphics cursor with a thumb wheel input device. Furthermore, he can use the same method to manually create and manipulate routes and to construct Restricted Operating Zones and Weapons Free Zones. All of these capabilities simplify the force level planning task of a FLAPS user.

SECTION IV

SYSTEM PERFORMANCE

Speed of processing is critical to automated force level and unit level planning systems. At the force level, planning effective use of intelligence information and force assets requires integrating and processing data from multiple sources quickly enough to meet planning schedule constraints, and respond to changes during the execution of the plan. Unit level planning must also be accomplished in a timely manner to ensure effective use of weapon system assets.

The FLAPS computer program is designed to be efficient for both force level and unit level planning. The algorithms employed by FLAPS for data base construction and updates have been structured and implemented to support efficient processing of planning functions. The planning algorithms for routing, weapons allocation, and EC aircraft allocation have been structured to arrive at solutions in minimal time.

This section provides information in the performance of the current FLAPS software against the scenario described in Tables 9 and 10 which covers the central European area.

Table 9. FLAPS Systems Performance Test Scenario

Geographic Area:	Lat 48 deg. N - 53 deg. N Long -2 deg. E - 16 deg. E
Lethality Space Area:	Lat 58 deg. N - 53 deg. N Long 9 deg. E - 16 deg. E
Statespace Cell Size:	2.5 nm x 2.5 nm
Altitude Levels:	200, 500, 1000 ft
Planning Objective:	6 OCA Target
Number of Staging Bases:	12
Attack Aircraft Type:	F-4, F-16, F-111
EC Aircraft Type:	EF-111A, EC-130H, F-4G
Number of LLTRs:	87

Table 10. Threat Laydown for Test Scenario

FIXED THREATS:

NUMBER/TYPE	RADIUS
25 SA-6	(18.5 nm radius)
15 SA-8	(9.0 nm)
20 SA-2	(20.0 nm)
10 ZSU-23-4	(3.0 nm)
10 SA-4	(43.0 nm)

EW/GCI THREATS:

NUMBER/TYPE	RADIUS
7 SQUATEYE	(51.2 nm)
2 TALLKING	(47.6 nm)
2 BARLOCK	(44.4 nm)
2 BACKNET	(42.8 nm)
2 FARMGATE	(42.8 nm)
2 SPOONREST	(42.8 nm)

MOBILE THREATS:

15 SA-6
19 SA-8

TOTAL: 80 FIXED SAMs
34 MOBILE SAMs
17 EW/GCI RADARS

For this test scenario, the objective is to plan the attack of 6 OCA targets using assets of 12 potential staging bases and EC aircraft. Note that the lethality space is smaller than the geographic area for the operations. This occurs when the lethality space (or statespace) is reduced to a size which

covers the area of the FEBA and the targets. It is not necessary for this depiction to extend back to all of the staging bases. This geographic and lethality space area was depicted in Figure 1.

Table 10 lists the types and numbers of threats considered in the test scenario. The distinction made between the fixed threats, the EW/OCI threat, and the mobile threats is that terrain masking is performed on the fixed and EW/CCI threats, while the mobile threats are not terrain masked. Fixed threats are those threats whose location is known, while mobile threats are those whose location is not precisely known. Figure 2 is a depiction of the threat laydown for this scenario.

System performance times for two computer systems are listed below. The VAX 11/785 is the system used for development purposes at SCT's Palo Alto Headquarters. Performance times are also shown for SCT's MicroVAX II which is currently being tested in Palo Alto. The MicroVAX II is an example of a small computer system that could host an operational version of FLAPS for force level, and perhaps unit level, planning.

Entering the commands NODES, ACCESS, ARCS, ROUTES, and ALLOCATE provides the initial data input and generates responses in the times listed as follows:

SYSTEM TIMING DATA (SECONDS)

	11/785		MicroVAX II	
	CPU	WALLCLOCK	CPU	WALLCLOCK
NODES	0.96	5.67	2.46	7.16
ACCESS	1.86	3.55	4.49	6.32
ARCS	36.88	46.65	100.03	119.64
ROUTE	0.64	1.70	1.33	3.20
ALLOCATE	0.13	1.33	0.17	0.51

Entering SUPPRESS results in calculation of suppressor effects on the statespace. The times for this response are

56.05	151.97	114.18	272.27

The REROUTE entry produces new routes that take advantage of the corridors created by suppressor resources. Times for this calculation

39.95	54.97	104.43	166.00

Input RESTORE to regenerate the statespace and routes so other corridor locations may be considered. This requires the times

50.81	110.12	123.31	240.97

Other entries and their times are

MASK THREAT	3.30	7.04	7.72	20.10
ADD THREAT (18 nm)	2.02	6.62	3.52	15.39
MASK THREAT	28.30	68.68	59.88	155.57
ADD THREAT (51 nm)	7.76	20.21	14.18	44.55
ADD STCH	5.90	11.70	11.89	27.65

Note that the MicroVAX II is about one half the speed of the VAX 11/785. The time required to update the threat data is critical for both force and unit level planning. A threat update consists of masking the threat and adding it to the statespace. In Section VII, methods are discussed to reduce the time required for the MicroVAX II to perform these functions.

Updating the data base using a command file is a relatively fast operation. Large data base revisions can be updated very rapidly - typically in less than 60 seconds for both machines. SCT recommends accomplishing major data base revisions using command files, since errors are recovered more easily. Unfortunately, there are no methods currently available for automatically building command files. These must be entered manually by the operator. This may be a very time consuming process. Updating a target, LLTR node, or threat requires one line in a command file. It will require around 30 seconds or more to manually enter each line in these command files.

A unit level system will perform many of the same basic functions as FLAPS. For example, terrain masking, threat analysis, and route generation are necessary at the unit level. The figures for the MicroVAX II may be used as an estimate of the performance of an efficient unit level system.

SECTION V

COMPUTER SYSTEM CONSIDERATIONS

There are several computer system considerations related to the implementation of FLAPS as an operational tool. At the force level, there are many large data base files which need to be created, maintained, and saved. The creation and maintenance of this data must be accomplished in a timely fashion using minimum computer core resources. The need for compatibility between force level planning and unit level planning also imposes computer system considerations on an operational unit level system.

SCT's goal has been to keep computer core, disk, and run time requirements as small as possible. Sometimes these goals conflict. For example, the number of disk reads can be reduced, but only at the expense of increasing the amount of core used. However, the result is faster run times. (See Section VII for further discussion.) The current FLAPS system has been tailored to keep core requirements to a minimum. This was done without sacrificing speed in the dynamic programming or terrain masking algorithms.

V.1 FORCE LEVEL REQUIREMENTS

The computer core requirements for the current FLAPS system are given in Table 11. This should be viewed as an estimate of the minimum computer core

required for a force level planning system. This data is based on performing force level planning for a geographic area covered by ATOC Sembach.

Table 11. FLAPS Computer Core Requirements - Force Level

COMPUTER CORE REQUIREMENTS	(BYTES)
STORAGE REQUIRED FOR DPA AND TERRAIN MASKING:	3,072,044
STORAGE REQUIRED FOR MOBILE THREAT MODEL:	1,000,896
STORAGE REQUIRED FOR LOCAL DATA:	351,080
STORAGE FOR DATA BASE MANAGER:	262,948
STORAGE REQUIRED FOR GRAPHIC DISPLAYS: (not including local memory within the Tektronix 4115B)	143,892
MISC. STORAGE:	198,013
CODE:	192,503
TOTAL EXECUTABLE	5,221,376

The current FLAPS executable requires approximately 5.2 megabytes of core. This is a large number; however, it is well within the range of currently available small computer systems. Note the dynamic programming and terrain masking algorithms require a large amount of computer storage, if they are to be executed quickly. Also note the Tektronix 4115B color display terminal is very memory intensive (although this memory is contained locally within the terminal).

The computer disk storage requirements for the current FLAPS system are given Table 12. This is an estimate of the minimum computer disk storage required for a force level planning system in the ATOC Sembach. The list contains only the required data files. The FLAPS executable, source files, object files, and command files are not included. It is not clear at this time

Table 12. FLAPS Disk Storage Requirements - Force Level

	DISK FILES	(BYTES)	
Data Base Tables	ALGP	1,024	
	ASTR	6,144	(static)
	CMDL	2,560	(static - currently not used)
	CURR	1,024	
	DISP	2,560	
	GEOM	1,536	
	LLTR	25,600	
	NODP	1,024	
	PBOR	49,664	(static)
	ROZ	3,072	
	SPED	269,824	
	STCH	22,016	
	STGB	4,096	
	SUPM	5,632	(static)
	SUPP	2,560	
	SWCH	1,024	(static)
	TG	2,048	
	THRT	28,672	
	TMDL	77,312	(static)
	TSTR	446,464	(static)
	VEHP	4,096	(static)
	WEAP	9,216	(static)
	WFZ	2,048	
Data Base Arrays	ALTG	9,728	(static - currently not used)
	ALTS	355,328	
	ARCS	38,400	
	ARPE	19,456	
	BYTE	6,843,392	(static)
	CL3D	9,728	(static - currently not used)
	ITGC	19,456	
	ITRC	19,456	
	MASK	384,000	
	NBOX	19,456	
	NLIS	19,456	
	NPOS	19,456	
	ROUT	19,456	
	STAT	355,328	
	SXPE	19,456	
	TGUS	19,456	
	TH2D	9,728	(static - currently not used)
	TH3D	1,027,584	
	TOBS	662,528	
	TRPE	19,456	
	TOTAL	10,859,520	

which files (besides the executable) will be required on an operational system. Data files which are static (or not currently being used) are noted as such.

The 10.8 megabytes of disk storage reflect the current test scenario. Increasing the number of threats, targets, staging bases, etc., will increase the amount of necessary storage. However, the volume of the largest arrays, BYTE and TH3D, does not depend on the number of threats or targets. It depends only on the size of the scenario and the statespace cells.

As changes are made to the system to make it operational, these requirements may alter substantially. BYTE and TH3D are the largest disk files used by FLAPS. The current byte packed terrain file (BYTE) is for the region 8 to 16 degrees east longitude and 48 to 54 degrees north latitude. If a larger terrain data file is needed in the future, then the BYTE file will expand as well. Currently there is only one TH3D file. If it becomes necessary to build multiple statespaces for the different airframes, then multiple TH3D files will follow. Also the current TH3D file contains danger at only three altitudes (200, 500, and 1000 feet). If more altitudes are required, then this file will become larger. In the current test scenario there are about one hundred fixed threats. Terrain masking information for these threats is stored in the TOBS array. If the number of fixed threat sites increases dramatically, then this file could become larger than both the BYTE and TH3D files.

The FLAPS program is numerically intensive and requires frequent access to the hard disk drive. The computer host for FLAPS has to be selected with these characteristics in mind. A floating point processor, an efficient data bus, fast memory access, and fast disk access are all necessary if the FLAPS program is to run efficiently. Small computer systems that meet these requirements are currently available.

V.2 UNIT LEVEL REQUIREMENTS

FLAPS is very similar to the system that could be used at the unit level for detailed mission planning. The basic functions of terrain masking, threat modeling, and route generation are inherent to such a system. Because these functions consume the most core and disk space, it is possible to use the FLAPS computer system can be used as a baseline for the requirements of a unit level system.

SCT feels that the major difference between a unit level system and a force level system, like FLAPS, is the size of the scenarios. Since tactical aircraft have limited range, a unit level system does not need the capacitiy to look at very large scenarios. The core and disk requirements already listed can be considered upper bounds for unit level needs.

Reducing the scenario size for the unit level system would reduce the core requirements. Specifically, the core required to execute the dynamic programming algorithm and the terrain masking algorithm could be reduced by about 1.5 megabytes. Therefore, SCT believes a unit level system could be designed to required between 3 and 3.5 megabytes of core. The disk storage requirements would probably be 10% to 25% smaller than those for the force level system.

SECTION VI

OPERATIONAL IMPLEMENTATION

The current FLAPS system has effectively demonstrated the capability of an automated force planning system - the goal of this effort. However, significant capabilities need to be added to make the system operational. These capabilities include real time interfaces, data base, and operative functionality.

VI.1 INTERFACES

The most obvious problem with the current system is the lack of real time interfaces with the key data bases relevant to mission planning. Table 13 lists these data bases.

Table 13. FLAPS Key Data Bases

Real time threat location data (LOCE interface)

Prioritized target list (DOO interface)

LLTR data (ACO interface)

Force status information

All of this data currently exists, or will exist, in the NATO ATOCs. Real time threat data is available through the LOCE system. The DOO, ACO, and force status data are available through the EIFEL system. This data will need to interface with the FLAPS system. One approach to providing such an interface is through simple file tranfers. This is a low risk and low cost approach. LOCE and EIFEL data could be stored as ASCII files on their host computers. When appropriate, the planner could tranfer these files to the FLAPS system computer host. The ASCII file format will reduce data compatibility problems. An interface program, residing on the FLAPS host computer, would read these files and produce FLAPS command files. The FLAPS data base could then be updated by reading these files. Currently, FLAPS command files are simple ASCII files while the actual FLAPS data base is not.

A more sophisticated system would be based on real time, automatic data base updates. This would require a real time operating system on the FLAPS host computer, real time communications links between computers, and sophisticated data management software. Designing such a system would be a major undertaking that must be included in future plans.

VI.2 DATA BASES

The data bases listed above are highly dynamic. Other data bases are also critical to the planning system, but they change much less frequently. These data bases include:

Table 14. FLAPS Dynamic Data Bases

DMA DTED terrain data

JMEM compatible data base for weaponeering

Threat models consistent with the LOCE data

A terrain data base covering much of central Europe is in the current FLAPS data base. If the current terrain (BYTE) file is not large enough, then a new file could be generated at low cost. A JMEM compatible data base is not currently contained in the FLAPS data base. The weaponeering methodology in the current FLAPS program is compatible with JMEM; however, a data base compatible with JMEM has not been generated to date. A data base for a limited number of target types (say 10 or 20) could be created for testing purposes at low cost.

TAC ZINGER threat effectiveness data for tactical SAM and AAA systems has been provided using SURVIAC. SCT has written and tested a program (SKIPPK) to convert this data into a form compatible with FLAPS. Recent discussions with USAFE personnel familiar with the LOCE system do not clarify whether these threat templates will be very useful in their current form. LOCE will provide precise information on EW and GCI radars; however, exact SAM and AAA positions will probably not be available. If this is the case, then threat templates which relate EW/GCI location and coverage with SAM and AAA coverage will have to be developed. Some modifications to the SKIPPK program will be necessary. This will be neither a high risk nor high cost change. The basic FLAPS approach is not changed.

VI.3 FUNCTIONAL CAPABILITY

With the fixed and static data bases listed previously. SCT feels the current FLAPS program would be an excellent tool for ATOC planners. A fully

operational system will require increased functional capability in the areas listed in Table 15.

Table 15. FLAPS Areas Requiring Increased Capabilities

Detailed consideration of operational scheduling constraints, including weather, tankers, and aircraft turn times

ATO and ATM formated output

EIFEL interface to output ATO

Menu driven user interface

All of these issues are being addressed in the FULL FLAPS effort and will not be discussed here.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

The FLAPS effort described in this report has effectively demonstrated the automated force planning concept. This effort has provided a valuable tool for defining requirements of the operational force planning system (FULL FLAPS), as well as defining requirements for data base interfaces at the ATOC level. SCT feels that the FULL FLAPS effort, currently in the planning stages, will produce a dynamic and responsive force planning system. Certain issues not addressed directly in the FULL FLAPS effort are discussed below. SCT feels that these issues are important to the long run success of both force and unit level planning systems.

VII.1 FORCE AND UNIT LEVEL COORDINATION

Coordination between the force and unit levels is critical for mission success in the European theater. The data and strategy used by the force level planner must be available to the unit level planner. Without this interface there is a significant chance the plan developed at the force level will be severely degraded. For example, the high probability of survival corridors may not be used by the attack aircraft. This will occur if the unit level planners do not understand (or do not have confidence in) EC aircraft allocation.

Fortunately, it is possible to have up to date planning data, powerful planning computers, and graphics terminals at the unit level. Critical planning data will be available through LOCE and the EIFEL network. Unit level planning computer systems are under development. SCT strongly recommends that every possible effort be made to insure the force and unit level systems are compatible. While each planning system has special requirements, maintaining a common technical approach for both systems will guarantee successful planning results.

VII.2 ADDITIONAL RESEARCH FOR KEY MATHEMATICAL MODELS

Additional research must be performed to support improved threat and EC effectiveness models. While considerable data currently exists, only limited amounts are directly applicable to force and unit level planning. Force and mission planning demands fast response time and the rapid consideration of many potential flight paths. Traditional trajectory analysis approaches, including detailed monte carlo simulations, are not feasible. Optimal path algorithms as used in FLAPS are available, and can produce very good flight plans in minimal time. However, the threat data needed to support these algorithms is currently very limited. A different type of data is needed for these models. Threat models used by optimal path algorithms should accurately include the effects of enemy command, control, communication systems, saturation effects (many attack aircraft saturating the defenses), and weather. These effects are difficult to model. It may even be impossible to model these effects exactly in a force or mission planning system. However, it should be possible to develop such models. They must approximate the data generated by more detailed simulations and support fast flight path routing algorithms.

The same is true for threat suppression. EW effectiveness models should be developed to show the effects of standoff and onboard self protection jamming, and degraded enemy command and control. These models should be compatible with the FLAPS approach. Such models would exhibit fast execution and compatibility with the threat models described above. Again, it may be necessary to sacrifice some accuracy in order to meet these goals. Given the critical need for force and mission planning aids, the payoff from this research would be substantial.

VII.3 ROUTING ALGORITHM RESEARCH

The dynamic programming algorithm used in FLAPS is very fast and produces minimum threat exposure routes. However, the applicability of this algorithm at the unit level is questionable given the aircraft inflight performance and navigation constraints. The current algorithm tends to produce routes with many turns, some of which can be quite sharp. These routes may be unacceptable to the pilot.

Other approaches under consideration by SCT include an algorithm which would only consider turns at predefined "delta" or navigation points. The optimum path would be constructed by connecting the best possible sequence of delta points. Probability of survival would be maximized while meeting fuel, navigation, and turn constraints. Such an algorithm could be developed with low cost/risk factors.

Other improvements to the routing algorithm could be made in the area of terrain following/terrain avoidance (TF/TA) and optimal clearance settings. The original AUTOPATH algorithm contained an option for altitude optimization. However, this algorithm tended to produce frequent altitude changes. For this reason, the option was not included in the FLAPS program. An effort to improve this model would be valuable.

VII.4 USE OF FLAPS AT HIGHER COMMAND LEVELS

The current FLAPS program would have valuable applications at NATO command levels above the ATOC. At the AAFCE level, FLAPS could be used to plan the Air Directive. At the ATAF level, FLAPS could be used to assist planners selecting LLTR's and allocating EC and attack assets. Modifications to the program would probably be necessary to support these functions.

A FLAPS system could also be used at the ATOC to support current operations personnel. Because FLAPS can rapidly compute attack aircraft allocations, it lends itself ideally to constructing ATM's in response to changes in targets, available assets, weather, and/or threats.

Finally, FLAPS is an excellend training aid for a facility like the Warrior Preparation Center (WPC). FLAPS could be used to construct ATO's during training exercises or train ATO planners.

VII.5 SMALL COMPUTER IMPLEMENTATION

Small computer implementation of FLAPS for force and unit level planning is a stated need for USAFE. SCT has begun to evaluate small computer architecture as it relates to FLAPS processing. SCT pruchased the MicroVAX II in support of this effort.

A specialized version of the FLAPS program has been developed to take maximum advantage of the available memory on the MicroVAX II. This reduces the number of time consuming disk accesses for certain tasks. The program is refered to internally as "Tuned FLAPS." To date, the effort has concentrated on the terrain masking and threat lethality computations. System performance data comparing this program with the current FLAPS program is given in Table 16.

Table 16. FLAPS Comparitive System Performance Data

SYSTEM PERFORMANCE (WALLCLOCK SECONDS)

FUNCTION	CURRENT FLAPS		TUNED FLAPS
	VAX 11/785	MICROVAX II	MICROVAX II
MASK 18.5 nm THREAT	7	20	6
ADD 18.5 nm THREAT	7	15	12
MASK 51.2 nm THREAT	69	156	44
ADD 51.2 nm THREAT	18	43	23
MASK ALL THREATS	1922	3671	1549
ADD ALL THREATS	902	2143	1219
(using the test scenario described in Section IV)			

The above table suggests that the terrain masking step can be speeded up considerably by using computer memory more efficiently. A useful force or unit level planning system must be able to update its threat data base very rapidly. Further research in this area may prove extremely useful.

APPENDIX A

FLAPS DATA BASES

There are two types of data structures in FLAPS: Tables and Arrays. Tables are record-oriented data structures which are under the direct control of the user. Arrays are matrix-oriented data structures which are created and maintained by the FLAPS software. Typically arrays contain a much greater quantity of data than tables.

A.1 TABLES

There are 22 tables defined in FLAPS. The names and descriptions of the tables are given below. Those tables which require input from the user are marked with an asterisk. The remaining tables, while important, will only occasionally be of interest to the planners. Many of these tables are created when the data base is first initialized, and then never change. These tables include TSTR, ASTR, and SWCH.

NAMES AND DESCRIPTIONS OF TABLES

TSTR		TABLE STRUCTURE
ASTR		ARRAY STRUCTURE
ALGP		ALGORITHM PARAMETERS
CURR		CURRENT STATUS
DISP		DISPLAY PARAMETERS
GEOM		COORDINATE TRANSFORMATIONS
LLTR	*	LLTR NODE PARAMETERS
NODP		NODE PARAMETERS
PBOR		POLITICAL BORDERS
ROZ		RESTRICTED OPERATING ZONES
SPED		SORTIE RECORDS
STCH	*	STOCHASTIC REGIONS
STGB	*	STAGING BASE PARAMETERS
SUPM		SUPPRESSION MODELS
SUPP	*	SUPPRESSOR TYPE
SWCH		VARIOUS SWITCHES
TG	*	TARGET PARAMETERS
THRT	*	FIXED THREAT LOCATIONS
TMDL		THREAT MODELS
VEHP		VEHICLE PARAMETERS
WEAP		WEAPON PARAMETERS
WFZ		WEAPON FREE ZONES

The first record of each table is a header record. This record contains information used by the file management software, and is uninteresting to the user. Data which is stored in a table begins in record 2. Some tables, such as the Algorithm Parameter (ALGP) Table have only two records. Other tables, such as the Threat Location (THRT) Table have many records. Within a table, the structure of each record is the same; that is, the records are all of identical length and are organized into the same sequence of items. For example, the following excerpt shows the contents of the first two and the last record in the threat location table. Each record (except the header record) corresponds to a single fixed threat. The same information, organized in the same fashion, exists for each threat.

```
CRSHOW -- RECORD      2     IDWORD=S001
```

```
          ID  =    S001
          ITYP=    SA-11
          XTH = 1.2082E+01 5.0615E+01 1.0000E+01
          PEX = 1.0000E+00
          IDC =  505291337
          IDM =  505291337

CRSHOW -- RECORD     3    IDWORD=S002
          ID  =    S002
          ITYP=    SA-11
          XTH = 1.2197E+01 5.0427E+01 1.0000E+01
          PEX = 1.0000E+00
          IDC =  505291337
          IDM =  505291337

CRSHOW -- RECORD    52    IDWORD=S051
          ID  =    S051
          ITYP=    SA-1B
          XTH = 1.7200E+01 4.8500E+01 1.0000E+01
          PEX = 1.0000E+00
          IDC =  505291337
          IDM =  505291337
```

The Threat Location Table has six items. Each item has a one to four character name (ID, ITYP, etc.). Notice that some items, such as *ID*, correspond to one element of data; while other items, such as XTH, correspond to more than one element. Each item is designated as character, integer or real. Mixed data types may not be associated with a single item.

The item structure of a record is very useful for manipulating the contents of the record. The first item in each record is the ID of the record. The ID is of character data type. A record may be accessed by its integer record number or by its character ID. The use of these two methods of accessing a record are discussed under the various data base commands in section 2.

The last two items of each record in every one of the FLAPS tables are the creation date (IDC) and modification data (IDM) of the record. These two items are not under the control of the user; he neither specifies their values nor can he change them. However, he can use the SHOW command to see what their values are. They are formatted as integer values in order that dates may be easily compared to see which one is later. The format is 'ymmddhhmm'. Thus, for example, the last record in the Threat Location Table above was created and modified at 13:37 on May 29, 1985 (IDC = IDM = 505291337).

A.1.1 THE TABLE STRUCTURE (TSTR) TABLE

The Table Structure Table contains the information which defines the structure of every other FLAPS table. Each record in TSTR describes one of the other FLAPS tables. TSTR is created by the program during a special initialization run in which the file ZDEFINE.DAT is read. The current version of ZDEFINE.DAT is included in Appendix A. This run is invisible to the user. The user should never attempt to ADD, DELETE, CHANGE or COPY the TSTR table.

The structure of the Table Structure Table is shown below. This excerpt may be recreated by typing "SHOW TSTR HELP".

TSTR TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
NAMT	CHO4	1	1	TABLE NAME
NXRC	INT	1	2	MAXIMUM RECORDS
IAFT	INT	1	3	EFFECT OF CHANGING TABLE
NIT	INT	1	4	NUMBER OF ITEMS
ITIT	CH24	1	5	TITLE OF TABLE
NAMI	CHO4	80	11	ITEM NAMES
ITYP	CHO4	80	91	ITEM TYPES
ISIZ	INT	80	171	ITEM SIZES
ITTL	CH24	80	251	TITLE OF ITEMS
IDEF	INT	80	731	DEFAULTABLE ITEM FLAG
IACC	INT	80	811	ITEM ACCESS CLASS
IEDT	INT	80	891	ITEM EDIT TYPE
PAR1	REAL	80	971	ITEM LOWER LIMIT
PAR2	REAL	80	1051	ITEM UPPER LIMIT
IAFI	INT	80	1131	EFFECT OF CHANGING ITEM
IDC	INT	1	1211	CREATION DATE
IDM	INT	1	1212	MODIFICATION DATE

The first item is the record ID -- it is the same as the name of the table which this record describes ('ASTR', 'ALGP', etc.). The next item is the maximum number of records allowed in the table, including the header record. The affect code is an integer whose meaning is described in the section on the CURR table (3.1.4). Then comes the number of items in the table and a 24 character title for the table. The next ten items are each of size 80, and describe the individual items within the table. Thus the number of items in any table must not exceed 80. NAMI is the one to four character name of the items; ITYP is the data type ('REAL', 'INT ' or 'CHnn', for a character item whose element length is nn characters). ITTL is a 24 character description of the item. IDEF is not currently implemented. IACC has the value of 0 for almost all items, but has the value of -5 for those few items which are not accessible to the user in ADD or CHANGE commands. IEDT, PAR1, PAR2 and IAFI are not currently implemented.

A.1.2 THE ARRAY STRUCTURE (ASTR) TABLE

The Array Structure Table contains the information which defines the structure of every FLAPS array. Each record in ASTR describes one of the FLAPS arrays. ASTR is created by the program during a special initialization run, in which the file ZDEFAR.DAT is read. This run is invisible to the user. The current version of ZDEFAR.DAT is included in Appendix B. The user should never attempt to ADD, DELETE, CHANGE or COPY the ASTR table.

The structure of the Array Structure Table is shown below. This excerpt may be recreated by typing "SHOW ASTR HELP".

ASTR TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
NAMA	CH04	1	1	ARRAY NAME
NXRC	INT	1	2	MAX NUMBER OF RECORDS
ITIT	CH24	1	3	TITLE OF ARRAY
IDC	INT	1	9	RECORD CREATION DATE
IDM	INT	1	10	RECORD MODIFICATION DATE

The first item is the record ID -- it is the same as the name of the array which this record describes ('ARCS', 'ARPE', etc.). The next item is the maximum number of records allowed in the array, including the header record. ITIT is a 24 character title for the array.

A.1.3 ALGORITHM PARAMETERS (ALGP) TABLE

The Algorithm Parameters Table defines the scenario and the statespace. This includes the geographic region over which the scenario is defined, and the statespace quantization level (cell size). Record 2 of this table must be properly defined before any processing starts.

A.1.3.1 ALGP TABLE USAFE -

The structure of the ALGP table is shown below. This table can be created by typing "SHOW ALGP HELP".

ALGP TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO4	1	1	ID = ALGP
DELE	REAL	1	2	LONGITUDE GRID(NM)
DELN	REAL	1	3	LATITUDE GRID(NM)
XMIN	REAL	1	4	MIN LON OF STATESPACE
XMAX	REAL	1	5	MAX LON OF STATESPACE
YMIN	REAL	1	6	MIN LAT OF STATESPACE
YMAX	REAL	1	7	MAX LAT OF STATESPACE
NALT	INT	1	8	NUMBER OF ALTITUDES
NDIR	INT	1	9	NUMBER OF DIRECTIONS
IDUM	INT	1	10	OF MASKING POINTS
IDVE	CHO4	1	11	VEHICLE NAME FOR STATES
ARMX	REAL	1	12	LAMDA - AIR DAMAGE
FLAM	REAL	1	13	LAGRANGE MULTIPLIER
ALTS	REAL	5	14	ALTITUDE GRID (M)
XSCL	REAL	1	19	MIN LON OF SCENARIO
XSCU	REAL	1	20	MAX LON OF SCENARIO
YSCL	REAL	1	21	MIN LAT OF SCENARIO
YSCU	REAL	1	22	MAX LAT OF SCENARIO
PCAP	REAL	5	23	PROB OF CLOBBER GRID
IDC	INT	1	28	RECORD CREATION DATE
IDM	INT	1	29	RECORD MODIFICATION DATE

The first item in the table is the ID which is always equal to ALGP. The next two items define the statespace cell size. DELE is the longitude increment and DELN is the latitude increment. Typically these two numbers are equal. Currently the values are both 2.4 nautical miles. The next four items define the statespace. XMIN and YMIN are the longitude and latitude of the southwest corner of the statespace. XMAX and YMAX define the northeast corner. As is standard for all the tables, the values are in decimal degrees; longitude is positive east and latitude is positive north. The variables XSCL, XSCU, YSCL, and YSCU, define the scenario. XSCL, and YSCL are the longitude and latitude of the southwest (lower) corner of the scenario. XSCU and YSCU are the longitude and latitude of the northeast (upper) corner of the scenario. The scenario must contain the statespace. NALT is the number of altitude levels that will be used in constructing the three dimensional statespace (TH3D). NALT may be as low as 1 and should never exceed 5. It is currently set to 5. NDIR is the number of directions used in generating the statespace. It must be set to 8 for this version of FLAPS. This corresponds to a 45 degree angular separation of adjacent directions. IDUM is the number of masking points and should be set equal to 2. IDVE is the ID of the vehicle for which the statespace is to be built. IDVE must match an ID for one of the Vehicle Parameters table (VEHP) records. The statespace will be built assuming that all vehicles are flying at the nominal velocity (VNOM in VEHP) for the vehicle specified by IDVE. ARMX is the air danger per second. It is applied to all transition costs in the statespace. A vehicle flying through enemy airspace is at risk even if it is not within the coverage of any known threats. FLAPS models this risk with ARMX. It should always be a very small number. FLAM is the Lagrange multiplier which is used to ensure that the routes generated by the dynamic programming algorithm

are direct and fuel efficient. It is also in the units of danger per second. ALTS is the list of above ground level clearance altitudes that are used in building the statespace. The altitudes are in meters. In building TH3D, threat exposure is calculated for each of these altitudes, for every threat. The first NALT values should be greater than 0. PCAP is the "constant probability of clobber grid" and is not now being used.

A.1.3.2 ALGP Table Usage -

The ALGP table defines both the scenario space and the statespace. It is critical that it be defined properly or else the threat modeling calculations, which are very time consuming relative the the rest of FLAPS, will be incorrect. The normal user should never have to change the values of ALGP. However, if that becomes necessary, the following information will be useful.

Please note that the statespace must be completely contained within the scenario space. The statespace must also be completely contained within the boundaries of the byte packed terrain data (BYTE) file. Please see sections 3.2.13, 3.2.10, and 3.2.17 for desciptions of TH3D, STAT, and BYTE.

The statespace contains what are called "transition costs". A transition cost is defined to be the negative log of the probability of survival going from one cell to another. The negative log probability of survival is often referred to as "danger". Because each cell is connected to eight other cells, there are eight transition costs per statespace cell. Threat lethalities are stored in the threat model table (TMDL) in the form of negative log probability of survival per second. To calculate a transition cost from a TMDL record requires

that the danger per second be multiplied by the amount of time it takes to fly from one cell to another, among other things. At this time, the FLAPS statespace is built for only one vehicle. This is in spite of the fact that planning is being performed for several vehicles types. Currently it is assumed that the differences in speed and threat capability between the F-4, F-16, and F-111 are small. The item IDVE is the ID of the vehicle for which the statespace will be built.

Routes generated using the dynamic programming algorithm are sensitive to the values of ARMX and FLAM. The current values, 5.0 E-6 and 1.5 E-4 respectively, are appropriate for the forcel level planning application. SCT recommends that the user not change these parameters.

A.1.4 THE CURRENT STATUS (CURR) TABLE

The Current Status Table consists of a single record of data. This record describes the current status of processing. CURR is updated by the program as a result of a PROC command, or an ADD, DELETE, CHANGE or COPY command to any other table. The user should never attempt to ADD, DELETE or COPY the CURR table. He should CHANGE the table only to change the graphical plotting device.

The structure of the Current Status Table is shown below. This excerpt may be recreated by typing "SHOW CURR HELP".

CURR TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO4	1	1	ID = CURR
IADD	INT	1	2	OF THREATS ADDED
IALT	INT	1	3	TERRAIN ALT INIDCATOR
IAOP	INT	1	4	ALTITUDE LEVEL
ICLO	INT	1	5	CLOBBER INDICATOR
ISTO	INT	1	6	OF STCH THREATS ADDED
ILST	CHO4	1	7	LAST COMMAND GIVEN
INDX	INT	1	8	INDEX OF LAST ARC DONE A
IPRO	INT	1	9	STATUS OF PROC COMMAND
ITYP	INT	1	10	TYPE OF LAST ARC DONE A
IMSK	INT	1	11	OF THREATS MASKED
IDEV	CHO4	1	12	INDEX OF LAST ARC DONE T
IDM1	INT	1	13	DEVICE CHARACTER
IDM2	INT	1	14	DUMMY NOT YET USED
IDM3	INT	1	15	DUMMY NOT YET USED
IDM4	INT	1	16	DUMMY NOT YET USED
IDM4	INT	1	17	DUMMY NOT YET USED
IDM5	INT	1	18	DUMMY NOT YET USED
IDM6	INT	1	19	DUMMY NOT YET USED
IDM7	INT	1	20	DUMMY NOT YET USED
IDM8	INT	1	21	DUMMY NOT YET USED
IDM9	INT	1	22	DUMMY NOT YET USED
IDMO	INT	1	23	DUMMY NOT YET USED
IDC	INT	1	24	RECORD CREATION DATE
IDM	INT	1	25	RECORD MODIFICATION DATE

The first item is the record ID and is always equal to CURR. Of the remaining items, only IAOP, IPRO and IDEV are currently used by the program. IAOP is the altitude level used in the altitude optimization algorithm of statespace construction. The user specifies this level in response to a prompt issued by the STATES AOPT and PROC commands as described in section 2. IDEV is the plotting device currently in use, as described in the DISPLAY command of section 2. IPRO is the status of processing as defined below.

```
IPROCU  = "STATUS OF PROCESSING"

          "=  0:  GEOMETRY TO BE DONE"
          "=100:  GEOMETRY OK;  STATESPACE TO BE CLEARED"
          "=120:  STATESPACE CLEARED;  MASKING TO BE DONE"
          "=140:  MASKING COMPLETE:  THREATS TO BE ADDED"
          "=150:  THREATS ADDED:  STCHS TO BE ADDED"
          "=160:  STCHS ADDED;  CLOBBER TO BE DONE"
          "=180:  CLOBBER OK;  AOPT TO BE DONE"
          "=200:  STATESPACE OK;  NODES TO BE DONE
          "=250:  NODES OK;  ACCESS TO BE DONE"
          "=300:  ACCESS OK;  ARCS TO BE COMPLETED"
          "=400:  ARCS OK;  ROUTES TO BE DONE"
          "=500:  ROUTES OK;  ALLOCATE TO BE DONE"
          "=600:  ALLOCATE OK"
```

A.1.4.1 CURR Table Usage -

The CURR table is changed by the user using the standard table CHANGE command. Only the IDEV item should be selected for changing. Possible values for this item depend on the available hardware configuration. Because the data type of this item is character, values like 4014 and 4115 which are normally treated as integers must be enclosed in double quotation marks with no embedded blanks. IDEV may take one of the following values.

CRT	24 x 80 alphanumeric display (poor resolution)
HP	Hewlett - Packard X - Y Plotter
PTX	Printronix High - resolution line printer

SEL	Selenar Board (VT-100 with special hardware)
"4014"	Tektronix 4014 and 4014 emulators (4014 emulation software is avaliable for the Macintosh)
"4115"	Tektronix 4115

The standard display device is the Tektronix 4115B. Users on other systems must make sure that IDEV is set appropriately. The FIND and LOCATE commands are only supported on the 4115B.

The value of IPRO is set automatically by the program. It is increased on a PROCESS command, according to the last algorithm successfully completed. Thus, for example, if the PROCESS command successfully completed all the way through ALLOCATE, IPRO would be set to 600; while, if it exited after successfully completing ACCESS, IPRO would be set to 300. The value of IPRO may be decreased on an ADD, DELETE, CHANGE or COPY command. In this case, IPRO is set to the smaller of its previous value and the value of the IAFT item in the Table Structure Table (See Section 3.1.1). Values for IAFT are as follows:

```
CRSHOW -- RECORD     2    IDWORD=ASTR
          IAFT=          0

CRSHOW -- RECORD     3    IDWORD=ALGP
          IAFT=          0

CRSHOW -- RECORD     4    IDWORD=CMDL
          IAFT=        100

CRSHOW -- RECORD     5    IDWORD=CURR
          IAFT=        600

CRSHOW -- RECORD     6    IDWORD=DISP
          IAFT=        600

CRSHOW -- RECORD     7    IDWORD=GEOM
          IAFT=          0

CRSHOW -- RECORD     8    IDWORD=LLTR
          IAFT=        200
```

```
CRSHOW -- RECORD     9    IDWORD=NODP
          IAFT=        250

CRSHOW -- RECORD    10    IDWORD=PBOR
          IAFT=        600

CRSHOW -- RECORD    11    IDWORD=ROZ
          IAFT=        600

CRSHOW -- RECORD    12    IDWORD=SPED
          IAFT=        600

CRSHOW -- RECORD    13    IDWORD=STCH
          IAFT=        100

CRSHOW -- RECORD    14    IDWORD=STGB
          IAFT=        200

CRSHOW -- RECORD    15    IDWORD=SUPM
          IAFT=        100

CRSHOW -- RECORD    16    IDWORD=SUPP
          IAFT=        100

CRSHOW -- RECORD    17    IDWORD=SWCH
          IAFT=        100

CRSHOW -- RECORD    18    IDWORD=TG
          IAFT=        200

CRSHOW -- RECORD    19    IDWORD=THRT
          IAFT=        100

CRSHOW -- RECORD    20    IDWORD=TMDL
          IAFT=        100

CRSHOW -- RECORD    21    IDWORD=VEHP
          IAFT=          0

CRSHOW -- RECORD    22    IDWORD=WEAP
          IAFT=        400

CRSHOW -- RECORD    23    IDWORD=WFZ
          IAFT=        600
```

Thus for example, if the value of IPRO is 600, and the user changes the LLTR file, then IPRO would be reduced to 200. A HELP STATUS command (section 2.1.1) would show that the STATESPACE is still good, but the NODES, ACCESS, ARCS, ROUTES, and ALLOCATE arrays are bad.

An example of the relevant items in the CURR table is shown below.

```
CRSHOW -- RECORD     2    IDWORD=CURR

          ID  =    CURR
          IAOP=          2
          IPRO=        600
          IDEV=    4115
          IDC =  505291337
          IDM =  505291353
```

A.1.5 THE DISPLAY (DISP) TABLE

The Display Table consists of three records of data which contain parameters necessary for writing to four different graphic display devices. The information in this table supports Lambert Conformal Projection plots. The information in this table is internal to the display algorithms. The user should never directly modify this table.

The structure of the DISP table is shown below. This table may be recreated by typing "SHOW DISP HELP".

DISPLAY TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
IDEV	CH04	1	1	PLOTTING DEVICE
LMIN	INT	1	2	MIN HORIZONTAL RASTER
MMIN	INT	1	3	MIN VERTICAL RASTER
LMAX	INT	1	4	MAX HORIZONTAL RASTER
MMAX	INT	1	5	MAX VERTICAL RASTER
XSCL	REAL	1	6	HORIZ RASTER / DEG LONG.
YSCL	REAL	1	7	VERT RASTER / DEG LAT.
XSUB	REAL	1	8	LONG AT HORIZ RASTER = 0
YSUB	REAL	1	9	LAT AT VERT RASTER = 0
XMIN	REAL	1	10	MIN LONG IN WINDOW (DEG)
YMIN	REAL	1	11	MIN LAT IN WINDOW (DEG)
XMAX	REAL	1	12	MAX LONG IN WINDOW (DEG)
YMAX	REAL	1	13	MAX LAT IN WINDOW (DEG)
IMIN	INT	1	14	MINIMUM I IN WINDOW
JMIN	INT	1	15	MINIMUM J IN WINDOW
IMAX	INT	1	16	MAXIMUM I IN WINDOW
JMAX	INT	1	17	MAXIMUM J IN WINDOW
XLB1	REAL	1	18	1ST LABELLED LONG. (DEG)
DXLB	REAL	1	19	DELTA LABELLED LONG(DEG)
NXLB	INT	1	20	NUMBER OF LABELLED LONGS
YLB1	REAL	1	21	1ST LABELLED LAT (DEG)
DYLB	REAL	1	22	DELTA LABELLED LAT (DEG)
NYLB	INT	1	23	NUMBER OF LABELLED LATS.
LAT1	REAL	1	24	1ST ZERO DISTORTION LAT
LAT2	REAL	1	25	2ND ZERO DISTORTION LAT
XCEN	REAL	1	26	CENTRAL LONGITUDE
RCON	REAL	1	27	DEG FR YMAX TO PROJ POLE
TSCL	REAL	1	28	ANGULAR SCALE (DEG/LONG)
LSCL	REAL	1	29	LAMBERT LON SCALE FACTOR
MSCL	REAL	1	30	LAMBERT LAT SCALE FACTOR

LCON	REAL	1	31	LAMBERT LON CONSTANT
MCON	REAL	1	32	LAMBERT LAT CONSTANT
DUM1	REAL	1	33	DUMMY NOT USED YET
DUM2	REAL	1	34	DUMMY NOT USED YET
DUM3	REAL	1	35	DUMMY NOT USED YET
DUM4	REAL	1	36	DUMMY NOT USED YET
DUM5	REAL	1	37	DUMMY NOT USED YET
IDC	INT	1	38	RECORD CREATION DATE
IDM	INT	1	39	RECORD MODIFICATION DATE

A.1.6 THE GEOMETRY (GEOM) TABLE

The Geometry Table consists of a single record of data. The Geometry Table is created by the program during the GEOM command. This is normally performed at program initialization and is invisible to the user. The user should never attempt to ADD, DELETE, CHANGE, or COPY the GEOM table. Most of this data is based on the data in the ALGP table. The scenario geometry is modified by changing ALGP.

The structure of the Geometry Table is shown below. This table may be recreated by typing "SHOW GEOM HELP".

GEOM TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH04	1	1	ID = GEOM
NI	INT	1	2	NUMBER OF LONGITUDES
NJ	INT	1	3	NUMBER OF LATITUDES
NK	INT	1	4	NUMBER OF AGLS
NL	INT	1	5	NUMBER OF DIRECTIONS
XMAX	REAL	1	6	MAXIMUM LONGITUDE
XMIN	REAL	1	7	MINIMUM LONGITUDE
YMAX	REAL	1	8	MAXIMUM LATITUDE
YMIN	REAL	1	9	MINIMUM LATITUDE
AL	REAL	5	10	STATESPACE ALTITUDES (M)
DX	REAL	3	15	STATESPACE DELTS (DEG,M)
IDEL	INT	8	18	DELTA I (LTH DIRECTION)
JDEL	INT	8	26	DELTA J (LTH DIRECTION)
XO	REAL	3	34	STATESPACE ORIGIN(DEG,M)
IDC	INT	1	37	RECORD CREATION DATE
IDM	INT	1	38	RECORD MODIFICATION DATE

The first item is the record ID and is always equal to GEOM. The next three items, NI, NJ, and NK give the number of statespace cells in the east, north and vertical direction. The number of cells is determined by the size of the statespace, the cell size, and the number of altitude levels specified in

ALGP. XMIN, YMIN, XMAX, and YMAX are the southwest and northeast corners of the statespace respectively. AL contains the altitude levels. DX(1) and DX(2) contains the north and east statespace cell size in decimal degrees. DX(3) is not currently being used. IDEL and JDEL define the eight transition directions and are used by the dynamic programming algorithm. XO is again the southwest corner of the statespace.

A.1.7 The Low Level Transit Route (LLTR) Table

The LLTR table defines the low level transit route (LLTR) network connecting the staging bases with the FEBA. This table must be constructed, or modified, by the user to model the transit route network in effect at the time the missions are to be flown. It contains one record for each LLTR node point. This record defines the ID, type and location of that node as well as its interconnections to other nodes. Records of this table may be referred to by their record number or the ID of the node as in the commands "SHOW LLTR 4" or "SHOW LLTR N008". Illustrated below is the description of the LLTR table structure which is generated by the FLAPS command "SHOW LLTR HELP".

NAME	TYPE	SIZE	LOC	TITLE
ID	CH08	1	1	ID OF TRANSIT ROUTE NODE
X	REAL	2	3	LONG-LAT OF LLTR NODE
CLNG	REAL	1	5	TRANSIT ROUTE CEILING
ITYP	INT	1	6	TRANSIT ROUTE TYPE
ICON	CH08	3	7	*LLTR NODE CONNECTIONS*
IDC	INT	1	13	RECORD CREATION DATE
IDM	INT	1	14	RECORD MODIFICATION DATE

The first item in each record is a unique ID for the LLTR node. This ID may be up to 8 alphanumeric characters long and the first character must be alpha. The second item consists of the longitude and latitude (in that order) of the node, given in decimal degrees according to the convention: Longitude +East/-West; Latitude +North/-South. Item three is not presently used by the program. Item four is the node type: type 0 - inactive node, type 1 - active entry node, type 2 - active intermediate node, type 3 - active exit node. Item five is a list of the other LLTR node IDs to which this node is connected; presently the length of this list may not exceed 3. A connection is defined

only for the direction from the staging base to the FEBA. Therefore, active exit points will have no connections and active entry points must have at least one connecting LLTR node. All LLTR nodes must be inside of the scenario space, or else they will be ignored by the program. In addition, all LLTR exit points must be inside of the statespace. This is because the dynamic programming algorithm (DPA) is used to generate routes from the LLTR exit points to the targets. The DPA can only be executed between two points if they are both inside of the statespace.

A.1.8 The Node Parameter (NODP) Table

The node parameter table NODP contains the number of nodes which are active in the specified scenario. NODP is an exception to the usual FLAPS convention that tables are defined by the user and arrays defined by the program - NODP consists of a single record (2) whose items are computed by the FLAPS command "NODES". The contents of this table may be examined with the command "SHOW NODP 2" but NODP records should never be added, copied, deleted or changed by the user. The description of the structure of NODP illustrated below is produced by the command "SHOW NODP HELP".

NAME	TYPE	SIZE	LOC	TITLE
ID	CRO4	1	1	ID = NODP
NSB	INT	1	2	NUMBER OF STAGING BASES
NTR	INT	1	3	NUMBER OF LLTR NODES
NTG	INT	1	4	NUMBER OF TARGETS
NTR1	INT	1	5	NBR OF LLTR ENTRY NODES
NTR2	INT	1	6	OF LLTR INTERMED NODES
NTR3	INT	1	7	NBR OF LLTR EXIT NODES
IDC	INT	1	8	RECORD CREATION DATE
IDM	INT	1	9	RECORD MODIFICATION DATE

Item one of the record is the table ID - NODP. Items two, three and four are the numbers of staging bases, LLTR nodes and targets, respectively, determined to be active and within the geographical region of interest. For example, inactive LLTR nodes (ITYP=0), targets outside the statespace boundaries, and staging bases and LLTR nodes out side of the scenario boundaries are not counted and are excluded from consideration in the mission planning problem. Items five, six and seven allocate the total in item three among the 3 LLTR node types: entry, intermediate and exit.

A.1.9 The Political Border (PBOR) Table

The PBOR table contains a list of long/lat points that outline the political borders between countries in a scenario. The PBOR table is used to display the country borders on the TEKTRONIX 4115. Each record can contain one or more borders between countries.

A.1.9.1 PBOR Table Structure -

The structure of the PBOR table is shown below. This table may be reproduced by typing "SHOW PBOR HELP".

PBOR TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH08	1	1	ID OF POLITICAL BORDERS
NPTS	INT	1	3	NBR OF PBOR BOUNDARY PTS
XPB	REAL	200	4	LONG-LAT OF BNDRY POINTS
IDC	INT	1	204	RECORD CREATION DATE
IDM	INT	1	205	RECORD MODIFICATION DATE

The first item in the PBOR table is the political border ID. This ID may be up to eight characters long and must begin with an alpha character. This ID usally describes the countries around the borders being plotted. The second item is the number of longitude/latitude points in each record. One hundred points is the maximum, with each longitude/latitude coordinates counting as one point. The third item is the political border points position as longitude and latitude. Longitude and latitude are in decimal degrees. The data points must be contiguous (all entered in either clockwise, or counterclockwise order).

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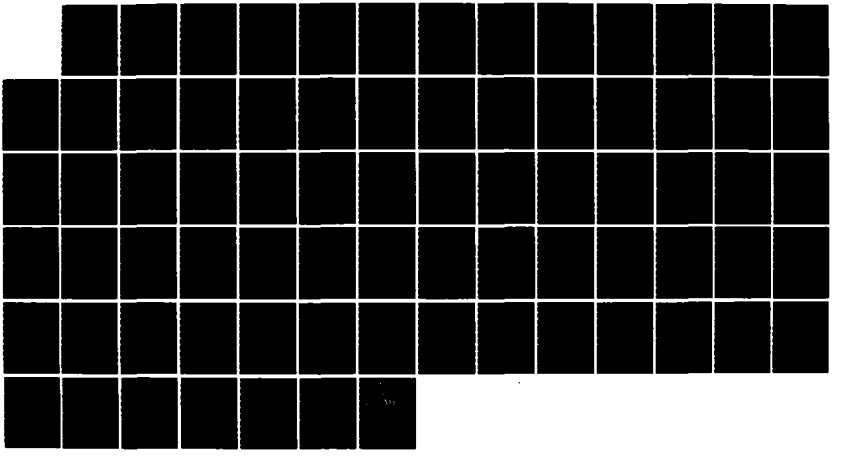

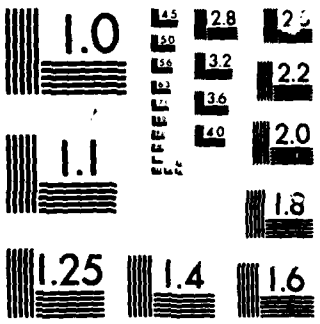

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

A.1.9.2 PBOR Table Usage -

The current PBOR files contain all of the political borders for Western Europe within the current scenario space (July 85 delivery). The user will not need to add or change these files. If the scenario is increased or moved, the PBOR records will have to be updated. If new boundary points are desired, records may can be added. The user could include roads, rivers or other cultural boundaries if data bases are available. The data may be displayed by using the BOUNDARY and MISSION options of the DISPLAY command.

An example of a PBOR record is shown below.

```
CRSHOW -- RECORD     5    IDWORD=EASGER

          ID  =    EASGER
          NPTS=         76
          XPB = 1.2150E+01 5.0317E+01 1.2217E+01 5.0317E+01
                1.2333E+01 5.0167E+01 1.2333E+01 5.0233E+01
                1.2500E+01 5.0400E+01 1.2833E+01 5.0467E+01
                1.2950E+01 5.0400E+01 1.3000E+01 5.0433E+01
                1.3050E+01 5.0517E+01 1.3167E+01 5.0517E+01
                1.3217E+01 5.0517E+01 1.3250E+01 5.0583E+01
                1.3300E+01 5.0567E+01 1.3417E+01 5.0633E+01
                1.3450E+01 5.0583E+01 1.3467E+01 5.0600E+01
                1.3500E+01 5.0633E+01 1.3517E+01 5.0717E+01
                1.3783E+01 5.0733E+01 1.3850E+01 5.0733E+01
                1.3883E+01 5.0750E+01 1.3900E+01 5.0800E+01
                1.4000E+01 5.0817E+01 1.4050E+01 5.0800E+01
                1.4083E+01 5.0800E+01 1.4217E+01 5.0867E+01
                1.4217E+01 5.0900E+01 1.4383E+01 5.0900E+01
                1.4400E+01 5.0933E+01 1.4300E+01 5.0967E+01
                1.4333E+01 5.0967E+01 1.4283E+01 5.0983E+01
                1.4267E+01 5.1000E+01 1.4300E+01 5.1050E+01
                1.4417E+01 5.1017E+01 1.4500E+01 5.1050E+01
                1.4500E+01 5.1017E+01 1.4583E+01 5.1000E+01
                1.4617E+01 5.0967E+01 1.4583E+01 5.0917E+01
                1.4650E+01 5.0933E+01 1.4617E+01 5.0867E+01
                1.4800E+01 5.0817E+01 1.4817E+01 5.0867E+01
                1.4967E+01 5.1000E+01 1.5000E+01 5.1167E+01
                1.5033E+01 5.1283E+01 1.5000E+01 5.1317E+01
                1.4983E+01 5.1400E+01 1.4967E+01 5.1467E+01
                1.4717E+01 5.1517E+01 1.4700E+01 5.1550E+01
                1.4733E+01 5.1617E+01 1.4717E+01 5.1667E+01
```

```
 1.4667E+01 5.1733E-01 1.4667E-01 5.1800E-01
 1.4633E+01 5.1800E-01 1.4583E-01 5.1833E-01
 1.4700E+01 5.1917E-01 1.4717E-01 5.2000E-01
 1.4767E+01 5.2067E-01 1.4683E-01 5.2100E-01
 1.4683E+01 5.2133E-01 1.4700E-01 5.2167E-01
 1.4700E+01 5.2233E-01 1.4600E-01 5.2267E-01
 1.4533E+01 5.2383E-01 1.4550E-01 5.2433E-01
 1.4617E+01 5.2500E-01 1.4600E-01 5.2533E-01
 1.4633E+01 5.2583E-01 1.4217E+01 5.2817E-01
 1.4133E+01 5.2833E-01 1.4167E-01 5.2867E-01
 1.4133E-01 5.2967E-01 1.4250E-01 5.3000E-01
 0.0000E-00 0.0000E+00 0.0000E-00 0.0000E+00
 0.0000E-00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E-00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
IDC =  505231728
IDM =  505231728
```

A.1.10 ROZ: RESTRICTED OPERATING ZONE TABLE

The restricted operating zone table is used to store the locations where the planner wishes to place restricted areas of flying. Each record will contain one area of restricted operating zones.

A.1.10.1 ROZ Table Structure -

The structure of the ROZ table is shown below. This table may be reproduced by typing "SHOW ROZ HELP".

ROZ TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO8	1	1	ID OF ROZ
NPTS	INT	1	3	NBR OF ROZ BOUNDARY PTS
X	REAL	20	4	LONG-LAT OF BNDRY POINTS
TON	REAL	1	24	TIME ON OF ROZ
TOFF	REAL	1	25	TIME OFF OF ROZ
IDC	INT	1	26	RECORD CREATION DATE
IDM	INT	1	27	RECORD MODIFICATION DATE

The first item in the ROZ table is the restricted operating zone ID. This ID may be up to eight characters long and must begin with an alpha character. This ID can refer to the area involved or anything else the user wishes. The second item is the number of boundary points of the area. There is a minimum of three boundary points (triangle shaped area) and a maximum of ten points (ten-sided polygonal area). The third item contains the vertices of the restricted operating zone as longitude and latitude. Longitude and latitude are in decimal degrees. The vertices must be contiguous (all entered in either clockwise, or counterclockwise order). The fourth item is the time of day the ROZ is on and the fifth item is the time of day the ROZ is off. At this time

TON and TOFF are not being used. TON and TOFF would be in decimal hours.

A.1.10.2 ROZ Table Usage -

The ROZ table is added by the user with the standard table ADD command. Records can be changed, deleted, or copied. The data may be displayed by using the RZ option in the DISPLAY command. At this time, ROZ's are only used for display purposes and will have no effect on the routes. It is assumed that the LLTR data is correct and no attempt is made to verify that ROZ's are in fact avoided by the current set of available LLTR's.

An example of a ROZ record is shown below.

```
CRSHOW -- RECORD    2    IDWORD=AHLEN

        ID  =    AHLEN
        NPTS=          3
        X   = 7.6330E+00 5.1667E+01 8.1670E+00 5.1583E+01
              7.7670E+00 5.1917E+01 0.0000E+00 0.0000E+00
              0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
              0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
              0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
        TON = 0.0000E+00
        TOFF= 0.0000E+00
        IDC =  505231728
        IDM =  505231728
```

A.1.11 SPED

The SPED table contains routes, or sorties, stored as a series of waypoints and a header. Each record of the SPED table contains one route. Records in the SPED table are created using the SELECT command. Refer to the description of the SELECT command in section 2.1.11 to see how and when SPED records may be created. Each SPED record is quite large relative to the other tables in FLAPS. This makes SPED records rather difficult to manipulate. Several features have been built into FLAPS to make using the SPED table as easy as possible.

Routes are stored in the SPED table to support three commands. First, the DISPLAY command reads SPED records in order to graphically display routes. Refer to the ROUT option in the DISPLAY command in section 2.1.9. Routes are also read out of the SPED file for threat exposure analysis. Refer to the ANALIZ command in section 2.1.12. Finally, routes stored in the SPED table may be printed out in a flight plan format. Refer to the PLAN option for the SHOW command in section 2.1.7 and the flight plan description in section 3.2.16.

A.1.11.1 Table Structure -

The structure of the SPED table is shown below. This table can be recreated by typing "SHOW SPED HELP".

SPED TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH12	1	1	SORTIE ID (USER CHOOSEN)
ISB	INT	1	4	STAGING BASE INDEX
ITG	INT	1	5	TARGET INDEX
PS	REAL	1	6	PROB OF SURVIVAL

PTH	REAL	1	7	PROB KILL DUE TO THREATS
DFLT	REAL	1	8	DISTANCE
TTOT	REAL	1	9	TAKE OFF TIME
TOT	REAL	1	10	TIME ON TARGET
NPT	INT	1	11	OF COORDS IN PATH
COOR	REAL	720	12	T,X,Y,A,HEADING,NODE
IDC	INT	1	732	RECORD CREATION DATE
IDM	INT	1	733	RECORD MODIFICATION DATE

Each SPED record is exactly 733 words long. The record represents a total route from the staging base to the target and back to the staging base. At this time, a maximum of 50 records may be stored in the SPED table. As with every FLAPS table, the first record contains header information, so that a maximum of 49 routes may be stored.

The first item in each record must be a unique ID. The ID may be up to 12 characters long, the first character should be an alpha. The second and third items in each SPED record are the indices of the sortie staging base (ISB) and target (ITG), respectively. These index numbers correspond to the NLIS array. The fourth item is the total route probability of survival (PS). The fifth is the probability of kill due to threats (PTH). The total probability of survival is the product of one minus the probability of kill due to threats and one minus a small probability of kill due to "air danger". The sixth item is the total route distance (DFLT). The seventh is the take off time (TTOT) in minutes. The eighth is the time on target (TOT) in minutes. The ninth item is the number of waypoints in the route (NPT).

Next, the actual coordinates of the waypoints are stored (COOR). There are six components of a waypoint. The first is the time in minutes at which the way point occurs, the second and third are the longitude and latitude both in decimal degrees, the fourth is the altitude (above ground level) in meters, the fifth is heading from north in degrees, and the sixth is an integer index. The integer index corresponds to the NLIS array and will be nonzero if the waypoint is a staging base, target or LLTR node. Each SPED record may contain up to 120 waypoints. Routes with fewer waypoints will contain zeros after the last waypoint.

A.1.11.2 SPED Table Usage -

Records in the SPED table may be shown, added, deleted, changed or copied just like any other table. However, because of the length of each SPED table record, care must be taken when working with the SPED table. SPED records should only be added using the SELECT command. The user should feel free to delete SPED records if some records are no longer needed or if more room is needed. The user should never have to change items in a specific SPED record or copy SPED records. The user may wish to show items in a SPED record header, such as DFLT or PS. If this is the case, the user should specify the items he wishes to see. Showing an entire SPED record is not recommended because of the length of the COOR item. The SHOW PLAN command was created to print out SPED records in an easily interpreted form. SHOW PLAN should be used if the user wishes to see the actual route waypoints.

When creating a SPED record using SELECT, FLAPS will automatically determine an ID if the user wishes. The ID is determined as follows: The first four characters of the SPED ID are the first four characters of the name of the staging base at which the route originated, the fifth character is an underscore ".", the sixth through ninth characters are the first four characters of the name of the target, the tenth character is an underscore, and the eleventh and twelfth characters are a sequence number between 01 and 09. For example, the first time a route from Ramstein AFB to target Caslav is put in the SPED table, the ID will be RAMS.CASL.01. If a second version of this route is put into the SPED table (say after suppression has been applied), then the ID will be RAMS.CASL.02. Of course the user can override this convention by inputing his own ID while executing SELECT.

Please note that the probability of survival and kill data is valid for the route at the time it was created only. If suppression is later applied or threats are added, the probability of survival data is not updated. The ANALIZE command computes probability of survival on the current statespace and should be used to check the impact of statespace changes on specific routes.

An example of a SPED record is shown below.

```
CRSHOW -- RECORD     2    IDWORD=SMAR.SZPR
          ID  =    SMAR.SZPR
          ISB =           1
          ITG =         133
          PS  = 1.5513E-01
          PTH = 8.4473E-01
          DFLT= 1.7600E+03
          TTOT= 0.0000E+00
          TOT = 9.1189E+01
          NPT =          52
          COOR= 0.0000E+00-1.7500E+00 5.1583E+01 1.2000E+02
                4.7937E+01 0.0000E+00 3.8942E+00-1.0000E+00
                5.2000E+01 1.2000E+02 1.0763E+02 0.0000E+00
```

2.4323E+01 4.0000E+00 5.1000E+01 1.2000E+02
1.2569E+02 0.0000E+00 4.2450E+01 7.6542E+00
4.9288E+01 1.2000E+02 1.0547E+02 0.0000E+00
4.4401E+01 8.1150E+00 4.9205E+01 1.2000E+02
1.1383E+02 0.0000E+00 4.6960E+01 8.6872E-00
4.9039E+01 1.2000E+02 1.0043E+02 0.0000E+00
5.0109E+01 9.4423E+00 4.8948E+01 1.2000E+02
8.6115E+01 0.0000E+00 5.2933E+01 1.0129E+01
4.8978E+01 1.2000E+02 8.5533E+01 0.0000E+00
5.5919E+01 1.0855E+01 4.9015E+01 1.2000E+02
5.6508E+01 0.0000E+00 5.8911E+01 1.1466E+01
4.9279E+01 1.2000E+02 5.2046E+01 0.0000E+00
6.1690E+01 1.2005E+01 4.9552E+01 1.2000E+02
1.2203E+02 0.0000E+00 6.5828E+01 1.2867E+01
4.9200E+01 1.2000E+02 1.1926E+02 0.0000E+00
6.7871E+01 1.3302E+01 4.9040E+01 1.2000E+02
9.0000E+01 0.0000E+00 6.9656E+01 1.3738E+01
4.9040E+01 1.2000E+02 0.0000E+00 0.0000E+00
6.9906E+01 1.3738E+01 4.9080E+01 1.2000E+02
1.3444E+02 0.0000E+00 7.0263E+01 1.3800E+01
4.9040E+01 1.2000E+02 0.0000E+00 0.0000E+00
7.0763E+01 1.3800E+01 4.9120E+01 1.2000E+02
1.8705E+01 0.0000E+00 7.1555E+01 1.3863E+01
4.9240E+01 1.2000E+02 3.1458E+02 0.0000E+00
7.1911E+01 1.3800E+01 4.9280E+01 1.2000E+02
0.0000E+00 0.0000E+00 7.6160E+01 1.3800E+01
4.9960E+01 1.2000E+02 3.1510E+02 0.0000E+00
7.7927E+01 1.3489E+01 5.0160E+01 1.2000E+02
3.4171E+02 0.0000E+00 7.9507E+01 1.3365E+01
5.0400E+01 1.2000E+02 5.5771E+01 0.0000E+00
8.5754E+01 1.4672E+01 5.0960E+01 1.2000E+02
6.2926E+01 0.0000E+00 8.6854E+01 1.4920E+01
5.1040E+01 1.2000E+02 4.4320E+01 0.0000E+00
8.7553E+01 1.5045E+01 5.1120E+01 1.2000E+02
0.0000E+00 0.0000E+00 8.7803E+01 1.5045E+01
5.1160E+01 1.2000E+02 4.4195E+01 0.0000E+00
8.9199E+01 1.5294E+01 5.1320E+01 1.2000E+02
3.9129E+01 0.0000E+00 9.1189E+01 1.5617E+01
5.1567E+01 1.2000E+02 2.7440E+02 3.0535E-39
9.3900E+01 1.4920E+01 5.1600E+01 1.2000E+02
3.1601E+02 0.0000E+00 9.4248E+01 1.4858E+01
5.1640E+01 1.2000E+02 2.7000E+02 0.0000E+00
9.4489E+01 1.4796E+01 5.1640E+01 1.2000E+02
2.2449E+02 0.0000E+00 1.0147E+02 1.3551E+01
5.0840E+01 1.2000E+02 1.8000E+02 0.0000E+00
1.0322E+02 1.3551E+01 5.0560E+01 1.2000E+02
2.1345E+02 0.0000E+00 1.0412E+02 1.3427E+01
5.0440E+01 1.2000E+02 2.2476E+02 0.0000E+00
1.0447E+02 1.3365E+01 5.0400E+01 1.2000E+02
1.6162E+02 0.0000E+00 1.0605E+02 1.3489E+01
5.0160E+01 1.2000E+02 1.3498E+02 0.0000E+00
1.0782E+02 1.3800E+01 4.9960E+01 1.2000E+02

```
 1.8000E-02 0.0000E-00 1.1332E-02 1.3800E-01
 4.9080E-01 1.2000E-02 2.2556E-02 0.0000E-00
 1.1368E-02 1.3738E-01 4.9040E-01 1.2000E-02
 2.7000E-02 0.0000E-00 1.1546E-02 1.3302E-01
 4.9040E-01 1.2000E-02 2.9934E-02 0.0000E-00
 1.1750E-02 1.2867E-01 4.9200E-01 1.2000E-02
 3.0221E-02 0.0000E-00 1.2164E-02 1.2005E-01
 4.9552E-01 1.2000E-02 2.3220E-02 0.0000E-00
 1.2442E-02 1.1466E-01 4.9279E-01 1.2000E-02
 2.3665E-02 0.0000E-00 1.2741E-02 1.0855E-01
 4.9015E-01 1.2000E-02 2.6554E-02 0.0000E-00
 1.3040E-02 1.0129E-01 4.8978E-01 1.2000E-02
 2.6612E-02 0.0000E-00 1.3322E-02 9.4423E-00
 4.8948E-01 1.2000E-02 2.8045E-02 0.0000E+00
 1.3637E-02 8.6872E+00 4.9039E-01 1.2000E+02
 2.9390E-02 0.0000E+00 1.3893E-02 8.1150E-00
 4.9205E-01 1.2000E+02 2.8549E-02 0.0000E+00
 1.4088E-02 7.6542E+00 4.9288E-01 1.2000E+02
 3.0667E+02 0.0000E+00 1.5901E-02 4.0000E+00
 5.1000E+01 1.2000E+02 2.8800E+02 0.0000E-00
 1.7944E+02-1.0000E+00 5.2000E-01 1.2000E+02
 2.2820E-02 0.0000E+00 1.8333E+02-1.7500E+00
 5.1583E+01 1.2000E-02 2.2820E+02 0.0000E-00
 0.0000E+00 0.0000E+00 0.0000E-00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E-00 0.0000E-00
 0.0000E+00 0.0000E+00 0.0000E-00 0.0000E+00
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00

 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
IDC =  505091409
IDM =  505091409
```

A.1.12 STCH: STOCHASTIC THREAT MODEL TABLE

The stochastic threat model is used for those threats that exhibit one or more of the following features. The exact location of the threat is not known. The threat is a mobile threat whose location varies with time. The threat is a group of threats that are spread out over an area (such as tanks along a road or an army division). This table contains the necessary information to describe the area that a stochastic threat can cover without terrain masking. The generic threat information for each threat is obtained from the threat model table (TMDL).

A.1.12.1 STCH Table Structure -

The structure of the STCH table is shown below. This table may be recreated by typing "SHOW STCH HELP".

STCH TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH04	1	1	THREAT ID
ITYP	CH08	1	2	THREAT TYPE NAME
XSC	REAL	3	4	THREAT LON,LAT, and ALT
EXNT	REAL	1	7	EXPECTED OF THREATS
PEX	REAL	1	8	PROB THREAT EXISTS
RUNC	REAL	1	9	RADIUS OF UNCERTAINTY
NBPS	INT	1	10	OF PTS ON STCH BORDER
XPBS	REAL	100	11	LON LAT OF NTH POINT
FGRD	REAL	1	111	RATIO OF INT/GEO GRID
IDC	INT	1	112	RECORD CREATION DATE
IDM	INT	1	113	RECORD MODIFICATION DATE

The first item in the table is the stochastic threat ID. This ID is four characters long, with the first character being an alpha. The second item is the generic threat type name. This name can be up to eight characters long with the first character being an alpha. The threat type provides a pointer into the threat model table. The third item is an array with three elements that gives the threat longitude, latitude, and altitude. This item is used when the threat is contained at one location with a radius of uncertainty. In this case, the variables containing the number of boundary points and the boundary point locations are ignored when calculating the stochastic area. The fourth item gives the expected number of threats to be found in the stochastic area. The fifth item gives the probability of existence for this number of threats in the stochastic area. The sixth item gives the radius of uncertainty for the location of this threat. The seventh item gives the number of points that describe the boundary of the stochastic area for this threat. A stochastic area can be described by up to 50 points. The eighth item is an array containing the longitude and latitude for each point that describes the boundary of the stochastic area. It is used when the number of boundary points is greater than one. Then the variables containing the threat location and radius of uncertainty are ignored. The boundary points must be the vertices of a convex polygon. They must also be entered contiguously (either all clockwise, or all counterclockwise). The ninth item is the ratio of the integration grid size to the statespace grid size. An appropriate value to use for this variable is 1.0.

A.1.12.2 STCH Table Usage -

The stochastic threat table is used when a threat is a mobile threat, an area threat, or there is poor information as to it's exact location. In the cases where the threat is a mobile or area threat, a convex polygonal model is used to describe the threat boundaries. When the threat is a point with a radius of uncertainty, a circular model is used to describe the threat boundaries. Terrain masking is not used when modeling stochastic threats.

The current version of FLAPS does not support automatic threat suppression nor threat exposure analysis for stochastic threats. In other words, if the user has stochastic threats in his statespace and he applies suppression using the SUPRESS command, then the stochastic threat will not be suppressed. Similarly, if threat exposure is calculated for a route using the ANALYZ command, the time in and time out of the stochastic threats will not be reported. However, the leg-by-leg probability of survival report will be correct.

A.1.13 The Staging Base (STGB) Table

The staging base table STGB defines the locations and resources of the staging bases from which missions are to be flown. It contains one record for each staging base and must be constructed by the user to define the collection of staging bases of interest to his mission planning problem. These records may be referred to by their record number or by the staging base ID as in the commands "DELE STGB 5" or "SHOW STGB RAMSTEIN". Illustrated below is a description of the structure of the STGB table produced by the command "SHOW STGB HELP".

THE STAGING BASE (STGB) TABLE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH08	1	1	ID OF STAGING BASE
X	REAL	2	3	LONG-LAT OF STAGING BASE
ITYP	CH04	1	5	TYPE OF AIRCRAFT AT BASE
NACR	INT	1	6	NUMBER OF AIRCRAFT
NWEP	INT	10	7	NUMBER OF WEAPONS
IDC	INT	1	17	RECORD CREATION DATE
IDM	INT	1	18	RECORD MODIFICATION DATE

The first item in each record is a unique alphanumeric ID for the staging base. This ID may be up to 8 characters long and the first character must be alpha. Item two is the location of the staging base given as longitude, latitude (in that order) in decimal degrees according to the sign convention: Longitude +East/-West, Latitude +North/-South. Item three defines the type of aircraft assumed to be present at the staging base. This item may be up to 4 alphanumeric characters long and must agree with the aircraft ID of the record in the vehicle parameters table VEHP which describes this aircraft. Item four

is the number of aircraft available at the staging base. This number is used by the allocation algorithm to insure that the proposed allocation of aircraft to targets is consistent with the aircraft resources. Item five is a list of the number of weapons of each type available at the staging base. The order of this list must be consistent with the order used in the items ISCL (table VEHP), FCIN (table VEHP), PDWP (table WEAP) and NAME (table WEAP). The present version of the FLAPS allocation algorithm does not perform a detailed accounting of numbers of weapons allocated - it simply checks that a non-zero number of the selected weapon type is available at the selected staging base.

A.1.14 The Suppressor Model (SUPM) Table

The Suppressor Model Table contains data about the generic capabilities of the three types of threat suppressors modeled in FLAPS. Each SUPM record corresponds to a type of suppressor: EF-111, Compass Call, or Wild Weasel. For each type of suppressor, the SUPM table describes how much of an effect individual suppressors will have on the nearby threats. The locations of the individual suppressors are contained in the suppressor position (SUPP) table.

A.1.14.1 SUPM Table Stucture -

The structure of the SUPM table is shown below. This table may be recreated by typing "SHOW SUPM HELP".

SUPM TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO8	1	1	SUPP MODEL IDENTIFIER
RAD	REAL	1	3	MAX RADIUS OF THE SUPPRE
ICAP	INT	1	4	SUPP CAPACITY
TYPE	REAL	25	5	LIST THRT TYPE EFFECTIVE
DEGR	REAL	25	30	DEGRADE THRT CAPACITY
IDC	INT	1	55	DATE SUPP MODEL CREATED
IDM	INT	1	56	DATE SUPP MODEL MODIFIED

The first item in the table is the suppressor model ID. This ID may be up to eight characters long. The first character should be an alpha. The second item is the suppressor radius (RAD) in nautical miles. This is the radius over which the suppressor will be effective. The third item is the suppressor capacity (ICAP). This is the number of threats that this type of suppressor can be effective against, at one time. The fourth item is a list of the threat types (TYPE) that this type of suppressor is effective against. Each threat type in this list must correspond to a threat model ID in the TMDL table. A maximum of 25 threat models may be listed. The fifth item is a list containing the threat model degrade factors (DEGR). This list must correspond to the list of threat types in TYPE. Each degrade must be a real number between 0.0 and 1.0.

A.1.14.2 SUPM Table Usage -

The SUPM table is much like the threat model table TMDL. Each one contains generic information about a system. A threat system, a SAM for example, in the case of TMDL; and an EW or hard kill suppression system in the case of SUPM. Data about the deployments of actual threats and suppression aircraft is contained in the threat table (THRT) and the suppressor position table (SUPP) respectively.

The user should be aware of several things when creating records in the SUPM table. Currently, the above ground level altitude of the suppressor is not being used in determing the suppressor radius of coverage. For planning purposes, the model will use the radius RAD, no matter how high or low each individual suppressor actually flies.

It is unrealistic to expect a single Wild Weasel to clear out a large number of SAMS. The capacity of the Wild Weasel is ultimately limited by the number of missiles it can carry. For this reason, a capacity factor has been included in the SUPM table. If the number of threats within the radius of coverage of a suppressor exceeds its capacity, then the suppressor effectiveness is downgraded by a factor equal to the the capacity of the suppressor divided by the number of threats within its coverage. For example, if ICAP=6 and DEGR=0.5, then as long as the number of threats within the radius of coverage is six or less, then each threat will be degraded by a factor of 0.5. However, if 10 threats were within the radius then each of them would be degraded by the factor 6/10 * 0.5 = 0.3. Only threat types matching the SUPM TYPE list are included in the calculation. If the user does not want to downgrade suppressor effectiveness in this way, he can set the suppressor capacity to a large number (like 1000000).

Degrades are applied to the threats in the following way. If a threat site (XTH in THRT) falls within the radius of coverage of a suppressor, and if the threat type is in the SUPM TYPE list, then a degrade is calculated. Nominally, the degrade will be the appropriate number in DEGR. The degrade number in DEGR corresponds to the position of the threat type in the TYPE list. If the suppressor capacity is not exceeded, this will be the degrade

contribution from this suppressor. If other suppressors are present, their degrade contributions are calculated in the same way. Finally, all of the contributions are factored in together and the threat's lethality will be degraded in the statespace (the SUPPRESS command). Each degrade is treated like an independent "probability of shutting the threat down." The effect of more than one suppressor on the same threat is multiplicative. If the capacity of one of the suppressors is exceeded, then the degrade contribution from that suppressor on each threat is downgraded as described above. FLAPS will warn the user of this during the SUPP command.

Finally, it is important that the degrades in DEGR be between 0.0 and 1.0. Negative degrades or degrades greater than 1.0 (100%) will produce errors in the statespace.

A.1.15 The Suppressor Position (SUPP) Table

The suppressor position table is used to store the locations where the planner wishes to place his available suppression assets. Each record in the suppressor position table will contain the position of one suppression asset.

A.1.15.1 SUPP Table Structure -

The structure of the SUPP table is shown below. This table may be reproduced by typing "SHOW SUPP HELP".

SUPP TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO8	1	1	SUPPRESSOR IDENTIFIER
TYPE	CHO8	1	3	SUPPRESSOR TYPE
XSU	REAL	3	5	LONG,LAT,TERR CLEAR ALT
IDC	INT	1	8	DATE SUPP REC CREATED
IDM	INT	1	9	DATE MODIFICATION

The first item in the SUPP table is the suppressor ID. This ID may be up to eight characters long and must begin with an alpha character. This ID need not refer to the type of suppressor that is being used. The second item is the suppressor type. This is an ID up to eight characters long and must match a suppressor model ID in the SUPM table. The third item is the suppressor position as longitude, latitude, and altitude above ground level. Longitude and latitude are in decimal degrees; altitude is in meters.

A.1.15.2 Using The SUPP Table -

The SUPP table may be added to or changed by the user with the standard table ADD and CHANGE commands, however the user will usually prefer to create SUPP records graphically. This can be done on a TEKTRONIX 4115B graphics display terminal using the LOCATE command. These records must be deleted in the usual way if the data is no longer appropriate. The data may be displayed using the SUPPRESSOR option of the DISPLAY command. A suppressor will not be effective against any threats if it has been placed poorly. Only threats whose centers are within the radius of coverage of a suppressor are affected. If the user does not see any effect after applying suppression, then he should check the suppressor positions and the suppressor model. If the degrades are very small or if the suppressor capacity is exceeded, then little effect will be seen.

A.1.16 The Software Switch (SWCH) Table

The SWCH table contains a number of "software switches" which control the way in which the program executes. Most of these switches are not being used in the current version of FLAPS and are only included to provide growth potential for the future. As the capabitlity of the models in FLAPS expand, these switches will become useful. That is why the switch table has been maintained. It should never be necessary for a normal user to modify the SWCH table. The table will be write protected during normal execution. The normal user may skip this section.

There are only two records in the SWCH table. The first is a header record and the second is a record containing the actual data.

A.1.16.1 SWCH Table Structure -

The structure of the SWCH table is described below. This table can be recreated by typing "SHOW SWCH HELP".

SWCH TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH04	1	1	ID
IAOP	INT	1	2	ALTITUDE OPTIMIZATION
IARP	INT	1	3	ARRAY PROCESSOR:1ON,0OFF
IBYT	INT	1	4	BYTE PACKED TERRAIN
ICLB	INT	1	5	CLOBBER
ICVB	INT	1	6	CL MODEL:0=BERMAN,1=GD
IDCN	INT	1	7	DECONFLICTION

IDUL	INT	1	8	DUAL CONTROL:0=Y,1,2=NO
IEND	INT	1	9	END POINTS OF ARCS
IFES	INT	1	10	INFEASIBLE TRANSITIONS
IGDS	INT	1	11	GD RUN
IGLD	INT	1	12	G LOAD:0=NO,1=YES
IMSK	INT	1	13	MASKING (- = GD APPROX)
IPCS	INT	1	14	CONST PROB OF CLOBBER
IREQ	INT	1	15	REQUANTIZATION
IRST	INT	1	16	RESTART ARCS
JRST	INT	1	17	RESTART TARCS
IRUF	INT	1	18	ROUGHNESS FILE
ISPD	INT	1	19	WRITE SPED FILE:YES R NO
ISRD	INT	1	20	LOOK AT ALL STATE SPACE
ITAV	INT	1	21	TARGET AVOID
ISHK	INT	1	22	SHRINK ACCESS BOX
ICAV	INT	1	23	LABEL DISPLAYS (SECRET)
IDM1	INT	1	24	DUMMY NOT USED YET
IDM2	INT	1	25	DUMMY NOT USED YET
IDM3	INT	1	26	DUMMY NOT USED YET
IDC	INT	1	27	RECORD CREATION DATE
IDM	INT	1	28	RECORD MODIFICATION DATE

The first item in the table is the ID which is always set to "SWCH". The IAOP, ICLB, ICVB, IFES, IGLD, IPCS, and IRUF switches all relate to three dimensional route planning and probability of clobber modeling. This capability is not yet available in FLAPS and these switches are not currently used. The IARP switch refers to a special hardware configuration which is currently not available, so this switch is not being used. The IBYT switch refers to the level of terrain data subsampling that is desired when reading the terrain data from the byte packed terrain data file, BYTE. This switch must be set to 1 in this version of FLAPS (no subsampling). The IDCN switch is for automated deconfliction of routes and is not now being used. The IDUL (dual control) switch will have a small effect upon the route generation algorithm. A setting of 0 is appropriate; a setting of 1 is also permissible. The IEND switch controls the way the route data is stored. A setting of 1 is appropriate for this version of FLAPS. The IGDS switch refers to certain constraints on routes

near the target area and is not now being used. The IMSK swch refers to the level of detail desired in the terrain masking algorithm. A setting of 2 is appropriate for this version of FLAPS. The requantization and restart switches IREQ, IRST, and JRST are not being used at this time. The ISPD switch refers to the SPED file and is not being used. The ISRD controls the way the statespace is read into the computer's core memory from disk. A setting of 0 is appropriate for this version of FLAPS. The target avoidance switch ITAV is not now being used. The shrink switch ISHK controls the way the "accessible nodes box" (NBOX) is constucted. A setting of 0 is appropriate for this version of FLAPS. The ICAV switch controls the labeling of the graphic displays and is not now being used. IDM1, IDM2, and IDM3 are dummy variables which are not now being used.

The following is a list of the current switch settings. This is what the user should see if he types "SHOW SWCH 2".

```
CRSHOW -- RECORD     2    IDWORD=SWCH
          ID  =    SWCH
          IAOP=          0
          IARP=          0
          IBYT=          1
          ICLB=          0
          ICVB=          0
          IDCN=          0
          IDUL=          0
          IEND=          1
          IFES=          0
          IGDS=          0
          IGLD=          0
          IMSK=          2
          IPCS=          0
          IREQ=          0
          IRST=          0
          JRST=          0
          IRUF=          0
          ISPD=          0
          ISRD=          0
```

```
ITAV=          0
ISHK=          0
ICAV=          0
IDM1=          0
IDM2=          0
IDM3=          0
IDC =  505091038
IDM =  505091038
```

A.1.17 The Target (TG) Table

The Target Table TG defines the IDs, locations, types, priorities, hardnesses, and desired damage levels of all targets of interest in the mission planning problem. This table must be constructed by the user and consists of one record for each target up to a maximum of 49. These records may be referenced by their record number or by the threat ID as in "SHOW TG 12" or "DELE TG MILOVICE". The description of the target table shown below is produced by the command "SHOW TG HELP".

TARGET TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH08	1	1	TARGET ID
XTG	REAL	2	3	LONG-LAT OF TARGET
CLAS	CH04	1	5	CLASSIFICATION OF TARGET
IPRI	INT	1	6	TARGET PRIORITY
ITYP	INT	1	7	TYPE OF TARGET
PDMN	REAL	1	8	MIN PROB DAMAG THRES TAR
IDC	INT	1	9	RECORD CREATION DATE
IDM	INT	1	10	RECORD MODIFICATION DATE

The first item of each record is a unique alphanumeric ID for that target. It may be up to 8 characters long and the first character must be alpha. Item two is the target location given as longitude, latitude (in that order) in decimal degrees according to the sign convention: Longitude +East/-West, Latitude +North/-South. Item three is a 4 character target class descriptor not presently used by the program. Item four is the integer valued priority assigned to the target. This item controls the order in which aircraft and weapons are allocated to targets. Thus a low value for this item indicates a high priority target. Item five is the target type which must be a positive

integer between 1 and 25. This item is used as an index to determine the targets vulnerability to the different weapon types. Therefore the value of this item must be consistent with the order of the values in the item PDWP (in the weapons table WEAP) which defines weapons effectiveness. Item six is the minimum probability of damage desired for the target and so its value must be a real number between 0 and 1. The allocation algorithm examines the single shot weapon effectiveness in item PDWP (in the table WEAP) and the aircraft weapon carrying capacity in item ISCL (in the vehicle parameters table VEHP) to determine how many aircraft and weapons are required to achieve this desired probability of damage. Thus, more aircraft (up to 10) will be allocated to this target as the value of the PDMN item approaches 1.0. Conversely, fewer aircraft (down to 2) will be allocated as its value approaches 0.

A.1.18 The Threat Location (THRT) Table

The Threat Location Table contains the necessary information to describe the location of fixed threats. These threats will have terrain masking applied to them before being included in the statespace.

A.1.18.1 THRT Table Structure -

The structure of the THRT table is shown below. This table may be recreated by typing "SHOW THRT HELP".

THRT TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH04	1	1	THREAT ID
ITYP	CH08	1	2	THREAT TYPE
XTH	REAL	3	4	GEOD LON,LAT,ELE OF DEF
PEX	REAL	1	7	PROBABILITY THREAT EXISTS
IDC	INT	1	8	RECORD CREATION DATE
IDM	INT	1	9	RECORD MODIFICATION DATE

The first item of this table is a threat ID. This ID can be up to four characters long with the first character being an alpha. The second item is a threat type name. This name can be up to eight characters long with the first character being an alpha. The threat type provides a pointer into the threat model table (TMDL) to get the generic information about this threat. The third item is a three element array containing the threat location in longitude,

latitude, and altitude. The fourth item is a probability of existence for this threat. record.

A.1.18.2 THRT Table Usage -

The threat location table is used by the modules that do terrain masking, adding and deleting threats from the statespace, threat suppression, and route analysis. The longitude and latitude is entered as decimal degrees with east longitude and north latitude being positive. Altitude is entered as decimal meters. The probability of existence is entered as a decimal from 0.0 to 1.0 .

A.1.19 The Threat Model (TMDL) Table

The Threat Exposure Model table contains the generic information for each type of threat that is used in the statespace. The model contains a threat exposure template that is symmetric around the downrange axis. This model assumes that the threat template is a vertical cylinder, and contains only one set of danger (negative log probability of survival) values for all altitudes.

A.1.19.1 TMDL Table Structure -

The structure of the TMDL table is shown below. This table may be recreated by typing "SHOW TMDL HELP".

TMDL TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO8	1	1	SPECIFIC THREAT MODEL ID
RMAX	REAL	1	3	MAXIMUM RANGE OF THREAT
DMIN	REAL	1	4	MIN LOG-PROB INSIDE RMAX
NDRG	INT	1	5	NUMBER OF DOWNRANGE PTS
NCRG	INT	1	6	NUMBER OF CROSSRANGE PTS
DRG1	REAL	1	7	1ST DOWNRANGE PT (NM)
CRG1	REAL	1	8	1ST CROSSRANGE PT (NM)
DDRG	REAL	1	9	DELTA DOWNRANGE (NM)
DCRG	REAL	1	10	DELTA CROSSRANGE (NM)
PLOG	REAL	200	11	PLOG AT NTH CROSSRANGE
DUM1	REAL	1	211	DUMMY NOT USED YET
DUM2	REAL	1	212	DUMMY NOT USED YET
DUM3	REAL	1	213	DUMMY NOT USED YET
DUM4	REAL	1	214	DUMMY NOT USED YET
DUM5	REAL	1	215	DUMMY NOT USED YET
HIGH	REAL	1	216	MAX THREAT HEIGHT
FLOR	REAL	1	217	MIN THREAT DEPRES. HT
IDC	INT	1	218	RECORD CREATION DATE

IDM INT 1 219 RECORD MODIFICATION DATE

The first item in the threat model table is a generic threat ID. This ID contains up to five characters, starting with an alpha. The second item is the maximum lethal range of the threat in decimal nautical miles. The third item is the minimum danger (DMIN) level that will be applied to the statespace within the threat's maximum radius. The user may set DMIN to a small danger level. This will tend to force the routes to fly around the threat's maximum radius, rather than to just avoid the threat's unmasked coverage. That is, even if a cell is terrain masked from a threat, a small amount of danger will be added to the statespace at that cell. DMIN is normally set to 0.0 in scenarios with dense threat coverage. A value of zero is appropriate in the european theatre. The fourth item is the integer number of downrange points up to a maximum of 20 points. If the number of downrange points is set to one, then the statespace algorithm uses the first value in the log probability of danger array to create a cookie cutter type threat template at all unmasked points. The fifth item is the integer number of crossrange points up to a maximum of 10 points. The sixth item is the range to the first downrange point in nautical miles. The seventh item is the range to the first crossrange point in nautical miles. The eight item is the range difference between downrange points in nautical miles. The ninth item is the range difference between crossrange points in nautical miles. The tenth item is an array that contains the danger template, which is defined as the negative log of probability of survival per second. Each set of twenty elements in this array contains all the downrange values for one crossrange setting. The tenth through fourteenth items are dummy items that are not used at this time. The fifteenth item is the maximum lethal height of the threat in

meters. The sixteenth item is the minimum lethal height of the threat in meters, to take into account the minimum depression angle on some threats.

A.1.19.2 TMDL Table Usage -

These threat templates are combined with the terrain masked templates for each threat to create a danger statespace. A special program named SKIPPK has been developed by SCT to format SURVIAC threat template data into a form compatible with the FLAPS TMDL table.

A.1.20 The Vehicle Parameters (VEHP) Table

The Vehicle Parameter table VEHP defines the ID, dynamics, fuel characteristics, weapon carrying capacity and radar profile for all the aircraft of interest in the mission planning problem. This table must be constructed by the user and consists of one record for each aircraft type. Records may be referenced by their record number or by the aircraft ID as in "DELE VEHP 3" or "SHOW VEHP F-16". The description of the VEHP table shown below is produced by the command "SHOW VEHP HELP".

VEHICLE PARAMETERS TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CHO4	1	1	AIRCRAFT ID
VNOM	REAL	1	2	AIRCRAFT VELOCITY (NM/S)
CLM	REAL	1	3	MAX CLIMB RATE (M/S)
DIV	REAL	1	4	MAX DIVE RATE (M/S)
FCAP	REAL	2	5	FUEL CAPACITY (POUNDS)
FCEG	REAL	2	7	FUEL CONSUMP. (EGRESS)
FCIN	REAL	20	9	FUEL CONSUMP. (INGRESS)
NMFC	INT	1	29	NUMBER OF FUEL CONFIGS.
ISCL	INT	20	30	STD. CONFIGURATION LOAD
RCS	REAL	8	50	RADAR CROSS SECTIONS
TRAD	REAL	1	58	MAX TURN RADIUS (M)
TYP	CHO4	1	59	AIRCRAFT TYPE
IDC	INT	1	60	RECORD CREATION DATE
IDM	INT	1	61	RECORD MODIFICATION DATE

Item one of each record is a unique alphanumeric ID for the aircraft type. It may be up to 4 characters long and the first character must be alpha. Item two is the nominal aircraft velocity in units of nautical miles per second. This item is used in the computation of flying time and threat exposure along a route. Items three and four are not presently used by the program. Item five

is a list of real numbers defining the aircraft fuel capacity in pounds as a function of the fuel configuration selected. Item six is a list of real numbers defining the aircraft fuel consumption rate during egress in pounds per second as a function of fuel configuration selected. Item seven is a list of real numbers defining the aircraft fuel consumption rates in pounds per second during ingress as a function of fuel configuration selected and weapon type being carried. This array is dimensioned (10,2). Item eight is the allowable number of fuel configurations - presently set at 2. Item nine is a list of integers defining the weapon carrying capacity of the aircraft as a function of fuel configuration selected and weapon type selected. The fuel configurationorder in items five, six, seven and nine must be consistent. Likewise, the weapon type order in items seven and nine must be consistent. Items ten through twelve are not presently used by the program.

A.1.21 The Weapons Effectiveness (WEAP) Table

The Weapons Effectiveness table WEAP defines the names and characteristics of the weapons of interest in the mission planning problem. This table consists of a single record (record 2) which must be created by the user. The contents of the table may be examined with the command "SHOW WEAP 2". The description of the WEAP table structure shown below is produced by the command "SHOW WEAP HELP".

WEAPONS EFFECTIVENESS TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
IDWP	CH04	1	1	ID = WEAP
PDWP	REAL	50	2	PK WEAP BY TG TYPE
NMTY	INT	1	52	NUMBER OF WEAP TYPES
NAME	CH08	10	53	NAME OF WEAPON
IDC	INT	1	73	RECORD CREATION DATE
IDM	INT	1	74	RECORD MODIFICATION DATE

The first item is the table ID, which is always "WEAP". Item two serves as a simplified version of the "Bomber's Encyclopedia". It consists of a 2 dimensional array of floating point numbers between 0 and 1. This array defines single shot probability of kill as a function of weapon type and target type. The array is currently dimensioned (10,25). The routing and allocation algorithms use these probabilities to determine the number of weapons and aircraft required to obtain the level of damage specified for each target. Therefore the weapon type index used in this list must be consistent with the corresponding index used in the items NWEP (table STGB), FCIN (table VEHP) and ISCL (table VEHP). Similarly, the target type index used in the list must be

consistent with the value of item ITYP (table TG). Item three is the number of weapon types (up to 10) being considered. Item four is a list of up to 10 alphanumeric weapon type names. These names may be up to 8 characters long and should be listed in the order consistent with the weapon type index used in item PDWP described above.

A.1.22 The Weapons Free Zone (WFZ) Table

The weapon free zone table is used to store the locations where the planner wishes to place weapons free air space. Each record will contain one weapons free zone.

A.1.22.1 WFZ Table Structure -

The structure of the WFZ table is shown below. This table may be reproduced by typing "SHOW WFZ HELP".

WFZ TABLE STRUCTURE

NAME	TYPE	SIZE	LOC	TITLE
ID	CH08	1	1	ID OF WEAPON FREE ZONE
NPTS	INT	1	3	NUMBER OF BOUNDARY POINT
X	REAL	20	4	LONG-LAT OF WFZ BNDRY PT
IDC	INT	1	24	RECORD CREATION DATE
IDM	INT	1	25	RECORD MODIFICATION DATE

The first item in the WFZ table is the weapon free zone ID. This ID may be up to eight characters long and must begin with an alpha character. This ID can refer to the area or anything the user wishes. The second item is the number of boundary points of the area. There is a minimum of three boundary points which would be plotted as a triangle and a maximum of ten which would be plotted as a polygon with ten sides. The third item is the weapon free zone position as longitude and latitude. Longitude and latitude are in decimal degrees. These points must be entered in contiguous order (either clockwise, or counterclockwise).

A.1.22.2 WFZ Table Usage -

The WFZ table is added by the user with the standard table ADD command. Records can be changed, deleted, or copied. The data may be displayed by using the WF option in the DISPLAY command. At this time, WFZ's are only used for display purposes and will have no effect on the routes. It is assumed that the LLTR data is correct and no attempt is made to verify that WFZ's are in fact avoided by the current set of available LLTR's.

An example of a WFZ record is shown below.

```
CRSHOW -- RECORD     2    IDWORD=DUSLDORF
          ID  =    DUSLDORF
          NPTS=           4
          X   = 6.2500E+00 5.1450E+01 7.0000E+00 5.1083E+01
                7.6667E+00 5.1500E+01 7.2500E+00 5.1767E+01
                0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
                0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
                0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
          IDC =  505231728
          IDM =  505231728
```

A.2 ARRAYS

This section describes the arrays used by FLAPS plus two special data structures; the flight plan output and the digital terrain elevation data. Arrays are matrix oriented data structures which are created and maintained by the FLAPS software. Each four character array name is associated with a random access disk file (see the OPEN command in section 2). These disk files each consist of 2 or more 2400 word records. The first record of each array is a header record. This record contains information used by the file management software; data which is stored in an array begins in record 2.

The actual record-oriented format of an array is uninteresting to the user; it only needs to be understood by the program developer. The names and descriptions of the FLAPS data base arrays are listed below.

NAMES AND DESCRIPTIONS OF ARRAYS

ARCS	ARC WAYPOINT ARRAY
ARPE	TARG INGRESS/EGRESS PERF
ITGC	TARG ACCESSIBLE TO STGB
ITRC	TREX ACCESSIBLE TO TREN
NBOX	LIST OF TG BOX CORNERS

NLIS	LIST OF NODES
NPOS	NODE POSITIONS
ROUT	ROUT NODES DIST AND PERF
SXPE	STGB TO LLTR EXIT PERF
TGUS	TARGET STATUS ARRAY
TRPE	LLTR TREE PERFORMANCE

A.2.1 THE ARCS COORDINATE (ARCS) ARRAY

The Arcs Coordinate Array contains the coordinates of the optimal path segments between the targets and their accessible LLTR exit points. Each target and LLTR exit point pair will have an associated ingress and egress arc. The arc performance data for the arcs is stored in the Arc Performance Array (ARPE).

The arcs are stored and displayed in the form of waypoints. Each arc is made up of at least two waypoints. Each waypoint has the following form: time (in hours), longitude (in decimal degrees), latitude (in decimal degrees), above ground level altitude (in meters), and a node index. Time is the elasped time from the beginning of the arc. The first waypoint will always have time equal to 0.0. The node index refers to the node ID stored in the NLIS array. Only the first and last waypoints will have nonzero indices.

The Arcs Coordinate Array is created by the ARCS command. The user may show the ARCS array after this command has been executed. To show an arc, the user should enter "SHOW ARCS". FLAPS will then prompt the user for a target ID or index. Either may be entered, whichever is more convenient. Then, FLAPS will prompt the user for an LLTR exit point ID or index. Again the user may enter either form The user may show the NLIS array to determine the correspondence between the node ID's and indices. If the target and LLTR exit point pair are not accessible, then FLAPS will give the user an error message. Accessible target and LLTR exit point pairs may be seen by showing the ITGC or ARPE arrays. The result of the SHOW ARCS command will be a listing of the ingress and egress arcs, in that order, as a sequence of waypoints. The form of the waypoints is described above.

The following table is the result of a "SHOW ARCS" command. The table could have been generated by entering:

SHOW ARCS CASLAV N150

or

SHOW ARCS 134 N150, or SHOW ARCS CASLAV 79

or

SHOW ARCS 134 79

WRARCS - ARRAY ARCS - 12 POINT INGRESS ARC FROM CASLAV (134) TO N150 (79)

TIME	LONGITUDE	LATITUDE	ALTITUDE	NODE
0.000	11.100	51.500	120.000	N150
0.133	11.436	50.240	120.000	
0.146	11.498	50.120	120.000	
0.158	11.622	50.040	120.000	
0.239	12.618	49.600	120.000	
0.248	12.742	49.600	120.000	
0.253	12.805	49.640	120.000	
0.266	12.991	49.640	120.000	
0.278	13.116	49.720	120.000	
0.433	15.418	49.680	120.000	
0.458	15.418	49.920	120.000	
0.462	15.383	49.950	120.000	CASLAV

WRARCS - ARRAY ARCS - 13 POINT EGRESS ARC FROM CASLAV (134) TO N150 (79)

TIME	LONGITUDE	LATITUDE	ALTITUDE	NODE
0.000	15.383	49.950	120.000	CASLAV
0.024	15.107	49.800	120.000	
0.034	15.045	49.720	120.000	
0.080	14.360	49.720	120.000	
0.139	13.738	49.320	120.000	
0.152	13.551	49.320	120.000	
0:158	13.489	49.280	120.000	
0.162	13.489	49.240	120.000	
0.168	13.427	49.200	120.000	
0.206	12.867	49.200	120.000	
0.339	11.498	50.120	120.000	
0.352	11.436	50.240	120.000	
0.485	11.100	51.500	120.000	N150

A.2.2 THE ARC PERFORMANCE (ARPE) ARRAY

The Arc Performance Array contains the distance and probability of survival for each arc generated by the "ARCS" command. For each target and each accessible LLTR exit point there is an ingress and egress arc. The accessible LLTR exit points for a given target can be seen by showing the ITGC array. The ARPE array contains the probability of survival and distance for each of these ingress and egress arcs.

The Arc Performance Array is closely related to the Arc Coordinate Array (ARCS). The data is stored seperately because only the performance data is needed to do the route construction (ROUT) and target allocation (ALLOCATE).

The Arc Performance Array is generated by the ARCS command. The user may show the this array after the ARCS command has been run. To show this array the user types "SHOW ARPE". FLAPS will then prompt the user to enter a target index, a target ID, "ALL", or "/". If the user wishes to see the performance of the arcs for a specific target, then he may enter the target index or target ID, whichever is more convenient. If all of the arc performances are required the user may enter "ALL". A "/" will cause the SHOW command to abort, and control will return to the main program. The output will be in the following form: "ID " refers to the target ID name, "INDEX" refers to the NLIS indices. The ingress and egress route distances and probabilities of survival are then shown. The following table was generated by FLAPS. It shows the arc performances for target "CASLAV". The user could have entered either:

SHOW ARPE CASLAV

or

SHOW ARPE 134

to generate this table.

WRPERF -- ARRAY ARPE -- ARC PERFORMANCES FROM CASLAV (134)

			INGRESS		EGRESS	
	ID	INDEX	DIST (NM)	PS	DIST (NM)	PS
1	N150	79	266.09	0.2050	279.40	0.2367
2	N151	80	251.35	0.2051	264.66	0.2369
3	N152	81	236.80	0.2051	250.11	0.2370
4	N153	82	222.60	0.2052	235.91	0.2371
5	N154	83	209.27	0.2053	222.58	0.2372
6	S088	69	178.88	0.2055	191.97	0.2374
7	S089	70	170.71	0.2056	179.71	0.2375
8	S092	71	156.91	0.2057	167.73	0.2376
9	S102	72	152.33	0.2061	158.22	0.2376
10	S120	73	144.71	0.2057	131.37	0.2378
11	S155	84	198.77	0.2054	211.59	0.2372

A.2.3 THE TARGET ACCESSIBILITY (ITGC) ARRAY

The Target Accessibility Array is a list of all of the paths that one can take to a given target provided he returns to his staging base on the shortest distance path. This array is used to determine which LLTR exit points should have arcs built from them to the target when the "ARCS" command is given. Building arcs is a time consuming process. By carefully applying accessibility rules, the number of arcs which need to be built can be kept to a minimum. For example, there is no need to build arcs to a target from a staging base (via a LLTR exit) if that staging base does not have weapons which will be effective against that target.

There is one ITGC record for every target which has at least one staging base accessible to it. Each line in the record corresponds to a potential path from a staging base to the target. The path is uniquely specified by giving the staging base, LLTR entry point and the LLTR exit point which would be used to reach the target. With this information, the actual LLTR node sequence can be retrieved from array ITRC.

The Target Accessibility Array has a one-to-one correspondence with the Staging Base to LLTR Exit Performance (SXPE) Array. That is, one would use the ITGC array to find the Staging Base to LLTR entry to LLTR exit paths that are feasible for a given target and then use the SXPE array to find the distance and probability of survival along the path from the Staging Base to the LLTR exit.

The Target Accessibility Array is generated by issuing the command "ACCESS". Changes to the STGB, LLTR, TG, WEAP and VEHP tables may make the ITGC array have stale data. The following ITGC record could have been generated by FLAPS by issuing the command "SHOW ITGC LEGNICA" or the command "SHOW ITGC 135". If all ITGC records are desired, the command would be "SHOW ITGC ALL".

WRACC -- THERE ARE 16 PATHS TO TARGET LEGNICA (135) IN ARRAY ITGC

	STAGING BASE		LLTR ENTRY		LLTR EXIT	
1	MILDENHA	(3)	N156	(17)	S088	(69)
2	MILDENHA	(3)	N156	(17)	S089	(70)
3	MILDENHA	(3)	N156	(17)	S092	(71)
4	MILDENHA	(3)	N156	(17)	S102	(72)
5	MILDENHA	(3)	N156	(17)	S120	(73)
6	MILDENHA	(3)	N156	(17)	S133	(74)
7	MILDENHA	(3)	N156	(17)	S134	(75)
8	MILDENHA	(3)	N156	(17)	S135	(76)
9	MILDENHA	(3)	N156	(17)	S136	(77)
10	MILDENHA	(3)	N156	(17)	S137	(78)
11	MILDENHA	(3)	N156	(17)	N150	(79)
12	MILDENHA	(3)	N156	(17)	N151	(80)
13	MILDENHA	(3)	N156	(17)	N152	(81)
14	MILDENHA	(3)	N156	(17)	N153	(82)
15	MILDENHA	(3)	N156	(17)	N154	(83)
16	MILDENHA	(3)	N156	(17)	S155	(84)

A.2.4 THE LOW LEVEL TRANSIT ROUTE ACCESS (ITRC) ARRAY

The Low Level Transit Route Access Array contains the optimal LLTR node sequences from a given LLTR entry point to every LLTR exit point which can be reached from that entry point. It also shows the distance through the network in nautical miles and the probability of arriving at the LLTR exit given one left from the LLTR entry. Even though the route from the LLTR entry point to the LLTR exit point is not contained in the statespace, and therefore is not exposed to any threat danger, the probability of survival will be slightly less than 1.0. This is due to the small "air danger" penalty. The same is also true for the TRPE and SXPE arrays. The distance and probability of arrival does not change on ingress or egress. The LLTR node sequence on egress is simply the reverse of the sequence on ingress. Therefore, one can read down the list to find the optimal path from the entry point to the exit (for ingress) and up the list to find the optimal path from the exit back to the entry point (for egress).

The Low Level Transit Route Access Array has a direct correspondence to the Transit Route Performance (TRPE) Array. That is, one would use the ITRC array to find the optimal node sequence through the LLTR network and the TRPE array to find the distance and probability of arrival along this path.

The ITRC array is created by issuing the NODES command. There are as many ITRC records as there are LLTR entry points which are accessible to at least one exit point. An individual ITRC record can be shown by specifying the alphanumeric LLTR entry point name or its unique NLIS index. All ITRC records can be displayed by giving the "SHOW ITRC ALL" command. The following sample ITRC table could have been generated by FLAPS by either issuing the "SHOW ITRC

N001" or "SHOW ITRC 14" commands.

WRTREE -- THERE ARE 3 EXITS ACCESSIBLE TO LLTR ENTRY POINT N001 (14)

BRANCH FOR LLTR EXIT N150 (79) DIST = 173.60 PA = 0.9946

1	N001	(14)
2	N002	(18)
3	N003	(19)
4	N004	(20)
5	N005	(21)
7	N150	(79)

BRANCH FOR LLTR EXIT N151 (80) DIST = 168.17 PA = 0.9948

1	N001	(14)
2	N002	(18)
3	N010	(22)
4	N011	(23)
5	N012	(24)
6	N013	(25)
8	N151	(80)

BRANCH FOR LLTR EXIT N152 (81) DIST = 165.04 PA = 0.9949

1	N001	(14)
2	N002	(18)
3	N010	(22)
4	N017	(26)
5	N018	(27)
6	N019	(28)
8	N152	(81)

A.2.5 THE MASK (MASK) ARRAY FILE

The mask array file is an internal file to the software and is not accessible to the user. The mask array is a temporary array file that is used during the masking function. It is stored in a polar coordinate system centered around the location of the threat. It consists of a set of rays emanating from the threat that are spaced equal angles apart in degrees. Along each ray is a set of points that are spaced equal distances apart. The minimum observable altitude is calculated for each point along the ray, and the ray is then written out to the mask file. Then, the mask file is read and transformed into X,Y coordinates. The new array is then stored in the file "TOBS" for later use in creating and modifying the statespace, implementing threat suppression, and analyzing routes. The parameters for creating the mask array are stored in file "MSKEXT". See SCT Technical Memo 5398-300 titled "TERRAIN MASKING ALGORITHM" for a detailed description of how the mask array file is created. This file is not available for showing by the user. The default dimensions for this array are shown below. Where the number of rays = 120 and the number of points along a ray = 125.

MASK = 1 1 120 125

A.2.6 THE NODE BOX (NBOX) ARRAY

The Node Box Array consists of the coordinates of a box around each target. The box is stored in the form: minimum longitude, maximum longitude, minimum latitude, and maximum latitude. All coordinates are in decimal degrees. The box defines the region over which the dynamic programming algorithm (DPA) will be run. Besides the target, the box contains all of the accessible LLTR exit points. These accessible LLTR exit points can be seen by showing the ITGC array. The optimal ingress and egress routes, from each LLTR exit point to the target will be contained within the box.

The Node Box Array is generated by the ACCESS command. The user may show this array after this command has been run. To show this array the user simply types "SHOW NBOX". No other inputs are required. The output will be in the following form: "ID " refers to the target ID name, "INDEX" refers to the NLIS indices. The box coordinates are in decimal degrees. The following table was generated by FLAPS after a "SHOW NBOX" was entered.

WRBOX -- ARRAY NBOX -- DPA BOX LIMITS

ID	INDEX	MIN LONG	MAX LONG	MIN LAT	MAX LAT
COCHSTED	1	11.0	12.9	49.2	52.0
KOTHEN	2	11.0	13.2	48.0	51.9
ZOLLSCHN	3	11.0	13.2	48.0	51.7
CHKEUDHZ	4	11.0	13.2	48.2	51.7
LEIPZIG	5	11.0	13.2	48.0	51.7
BRANDIS	6	11.0	13.2	48.2	51.7
DESSAU	7	11.0	12.9	49.2	52.0
KARLOVY	8	11.0	13.2	48.0	51.7
DOBRANY	9	11.0	13.4	48.0	51.7
ZATEC	10	11.0	13.8	48.0	51.7
PANENSKY	11	11.0	14.1	48.0	51.7
DREWITZ	12	11.0	14.7	49.4	52.0

PRESCHEN	13	11.0	14.8	49.4	51.8
PRESHYST	14	11.0	14.9	48.0	51.9
ROTHENBG	15	11.0	15.1	48.0	51.7
BAUTZEN	16	11.0	14.7	49.2	51.7
PRAGUE	17	11.0	14.4	48.0	51.7
KLECANY	18	11.0	14.5	48.0	51.7
MILOVICE	19	11.0	15.1	48.0	51.7
SZPROTAW	20	11.0	15.8	48.0	51.7
CASLAV	21	11.0	15.5	49.2	51.7
LEGNICA	22	11.0	16.1	48.0	51.7

A.2.7 THE NODE LIST (NLIS) ARRAY

The Node List Array is an ordered list of all active nodes in the current scenario. The nodes are ordered in the sense that they are grouped by type. That is, the first entries in the list are the staging bases. Next comes the LLTR entry points, followed by the LLTR intermediate points and then the LLTR exit points. At the end of the list is the targets.

The Node List Array only contains active nodes. Therefore, it does not include any staging bases or LLTR points that are not contained within in the scenario boundaries. Similarly, it does not include any targets that do not lie within the statespace boundaries. It also excludes LLTR nodes which are turned off. Keeping this list as small as possible by excluding nodes that will not be usable increases processing speed and minimizes computer memory usage.

The structure of NLIS is very simple since it only has two elements: the eight character alphameric node name and its unique integer index. These indices can be used in commands to specify a node instead of typing in the alphameric node ID. Care must be taken that a current version of NLIS is used since the indices can change as nodes become active or inactive (i.e. when the NODES command is given after changing STGB, LLTR or TG data bases or changing the statespace or scenario boundaries).

There is only one Node List Array record. Usually, it is suggested that the Node Position Array (NPOS) be used since it contains all of the information in NLIS and the node position information.

The Node List Array is generated by the NODES command. To show this array the user simply types "SHOW NLIS". The following table was generated by FLAPS by issuing the "SHOW NLIS" command.

WRLIS -- ARRAY NLIS LIST OF ID NAMES

INDEX	ID NAME
1	SMARSTON
2	LAKENHTH
3	MILDENHA
4	BENTWATE
5	BITBURG
6	SPANGDAH
7	HAHN
8	RAMSTEIN
9	SEMBACH
10	LAHR
11	SOLLING
12	WIESBADN
14	N001
15	N031
16	S079
17	N156
18	N002
19	N003
20	N004
21	N005
22	N010
23	N011
24	N012
25	N013
26	N017
27	N018
28	N019
29	N023
30	N024
31	N025
32	N026
33	N027
34	N028
35	N029
36	N030
37	S070
38	S071
39	S080
40	S081
41	S082
42	S083
43	S084

44	S085
45	S086
46	S087
47	S091
48	S097
49	S098
50	S099
51	S100
52	S101
53	S112
54	S113
55	S114
56	S115
57	S116
58	S117
59	S118
60	S119
61	S126
62	S127
63	S128
64	S129
65	S130
66	S131
67	S132
68	N157
69	S088
70	S089
71	S092
72	S102
73	S120
74	S133
75	S134
76	S135
77	S136
78	S137
79	N150
80	N151
81	N152
82	N153
83	N154
84	S155
114	COCHSTED
115	KOTHEN
116	ZOLLSCHN
117	CHKEUDHZ
118	LEIPZIG
119	BRANDIS
120	DESSAU
121	KARLOVY
122	DOBRANY
123	ZATEC
124	PANENSKY

125	DREWITZ
126	PRESCHEN
127	PRESHYST
128	ROTHENBG
129	BAUTZEN
130	PRAGUE
131	KLECANY
132	MILOVICE
133	SZPROTAW
134	CASLAV
135	LEGNICA

A.2.8 THE NODE POSITION (NPOS) ARRAY

The Node Position Array is very similar to the Node List Array (NLIS). It contains all of the NLIS information and all of the comments about NLIS apply to NPOS (see section 3.2.7). The major difference between the two arrays is that NPOS also includes the longitude and latitude positions of the nodes (in decimal degrees with the convention that east is positive for longitude and north is positive for latitude).

It is suggested that the NPOS list be used instead of the NLIS since it contains more information and is therefore more useful. The NPOS array is generated by the NODES command and will change when this command is given if there have been changes made to the STGB, LLTR or TG data bases or to the boundaries of the statespace or scenario. The following is an example of a Node Position Array generated by FLAPS by issuing the "SHOW NPOS" command.

WRPOS -- ARRAYS NPOS

ID NAME	INDEX	LONG	LAT
SMARSTON	1	-1.75	51.58
LAKENHTH	2	0.58	52.40
MILDENHA	3	0.50	52.37
BENTWATE	4	1.42	52.13
BITBURG	5	6.53	49.97
SPANGDAH	6	6.67	49.93
HAHN	7	7.25	49.93
RAMSTEIN	8	7.57	49.43
SEMBACH	9	7.88	49.50
LAHR	10	7.93	48.37
SOLLING	11	8.08	48.78
WIESBADN	12	8.33	50.05
N001	14	6.94	50.45
N031	15	7.07	49.59
S079	16	7.65	49.29
N156	17	-1.00	52.00
N002	18	7.44	50.45
N003	19	7.99	50.78
N004	20	8.59	51.03

N005	21	9.38	51.19
N010	22	7.90	50.45
N011	23	8.28	50.60
N012	24	8.92	50.83
N013	25	9.50	51.02
N017	26	8.50	50.43
N018	27	9.05	50.64
N019	28	9.60	50.78
N023	29	7.21	50.09
N024	30	7.65	50.18
N025	31	8.46	50.24
N026	32	8.97	50.29
N027	33	9.12	50.50
N028	34	9.56	50.60
N029	35	9.53	50.37
N030	36	6.95	49.89
S070	37	10.63	49.76
S071	38	10.87	50.09
S080	39	8.11	49.20
S081	40	8.91	49.14
S082	41	9.31	49.16
S083	42	9.98	49.30
S084	43	10.32	49.44
S085	44	10.07	49.14
S086	45	10.51	49.36
S087	46	11.06	49.71
S091	47	11.20	49.40
S097	48	8.69	49.04
S098	49	9.44	48.95
S099	50	10.13	48.98
S100	51	10.85	49.02
S101	52	11.47	49.28
S112	53	8.25	48.98
S113	54	8.34	48.66
S114	55	8.84	48.62
S115	56	9.45	48.64
S116	57	10.02	48.63
S117	58	10.75	48.73
S118	59	11.33	48.82
S119	60	12.12	49.14
S126	61	8.52	48.35
S127	62	8.98	48.36
S128	63	9.55	48.32
S129	64	10.36	48.27
S130	65	11.13	48.46
S131	66	11.79	48.65
S132	67	12.22	48.93
N157	68	4.00	51.00
S088	69	11.58	50.10
S089	70	11.55	49.76
S092	71	11.91	49.74
S102	72	12.01	49.55

S120	73	12.70	49.38
S133	74	12.87	49.18
S134	75	13.01	48.99
S135	76	12.54	48.55
S136	77	11.62	48.33
S137	78	12.19	48.17
N150	79	11.10	51.50
N151	80	11.10	51.25
N152	81	11.10	51.00
N153	82	11.10	50.75
N154	83	11.10	50.50
S155	84	11.10	50.25
COCHSTED	114	11.38	51.87
KOTHEN	115	12.00	51.75
ZOLLSCHN	116	12.12	51.27
CHKEUDHZ	117	12.25	51.42
LEIPZIG	118	12.45	51.43
BRANDIS	119	12.67	51.32
DESSAU	120	12.20	51.82
KARLOVY	121	12.88	50.22
DOBRANY	122	13.28	49.67
ZATEC	123	13.60	50.37
PANENSKY	124	13.93	50.32
DREWITZ	125	14.55	51.87
PRESCHEN	126	14.65	51.65
PRESHYST	127	14.72	51.70
ROTHENBG	128	14.97	51.37
BAUTZEN	129	14.53	51.20
PRAGUE	130	14.27	50.12
KLECANY	131	14.40	50.22
MILOVICE	132	14.93	50.23
SZPROTAW	133	15.62	51.57
CASLAV	134	15.38	49.95
LEGNICA	135	15.99	51.22

A.2.9 The Route (ROUT) Array

The array ROUT contains a summary of the hypothetical sorties generated by the command "RO". Each sortie consists of a round trip route-aircraft-weapon combination which is optimal for its target and staging base. The criterion for optimality is to minimize the expected number of lost aircraft among all feasible route-aircraft-weapon combinations. Feasible here means that the proposed combination is consistent with the aircraft fuel and weapon characteristics defined in table VEHP, and achieves the probability of damage specified for the target in table TG.

The hypothetical sorties assigned to a particular target may be examined using the "SHOW" command by specifying either the target index or the target ID as in "SHOW ROUT 119" or "SHOW ROUT LEGNICA". In addition all hypothetical sorties may be examined with the command "SHOW ROUT ALL". Illustrated below is the summary of a sortie assigned to target Legnica.

T A R G E T : LEGNICA PD ACHIEVED : 0.9984

	STAGING BASE	LLTR ENTRY	LLTR EXIT	DIST (NM)	PS	A/C	WEAP TYPE	EXP LOSSES
IN	MILDENHA	N156	S102	928.7	0.876			
EG	MILDENHA	N156	S102	930.6	0.919			
TOTAL				1859.3	0.805	2 F111	GB12	0.390

The probability of target damage (PD) shown in this summary represents only the effect of the proposed weapons package on the target - it does not reflect the probability of survival (PS) of the proposed route. Thus, the value of PD must be regarded as a probability of damage assuming the successful arrival of the aircraft at the target.

The detailed routes for the sorties in the ROUT array may be displayed graphically by using the DISPLAY ROUTE command and analyzed for threat exposure using the ANALIZ command. However it is first necessary that the routes be selected with the SELECT command.

A.2.10 THE STATESPACE (STAT) ARRAY

The Statespace Array is an internal file that is used by the software and is not available for showing to the user. It is stored in an X,Y coordinate system. The statespace array file covers the operational area of interest for one operational altitude. The parameters for the statespace array are stored in the parameter files "ALGP" and "GEOM". "STAT" contains the danger values for a given altitude. Prior to applying suppression, this data is derived from the three dimensional statespace array "TH3D". The PROCESS and STATESPACE ALTOPT commands, described in section 2, prompt the user to indicate which altitude level he wants loaded into "STAT". The SUPPRESS command, described in section 2.1.4, re-calculates STAT to take into account the lower levels of danger produced by the suppression assets. The "STAT" array is used to display danger contours, create minimum lethality routes from the staging base to the targets and back, and to analyze routes. The current default dimensions for this array are as shown below, where the number of flight directions = 8, the number of altitudes = 1, the number of longitude increments = 101, the number of latitude increments = 114. These file dimensions are printed out when STAT is opened by the initialization file ZCONTNU.DAT.

STAT = 8 1 101 114

A.2.11 THE STAGING BASE TO LLTR EXIT PERFORMANCE (SXPE) ARRAY

The Staging Base to LLTR Exit Performance Array gives the distance in nautical miles and probability of arrival performance data for the optimal path from a staging base to a LLTR exit. This array corresponds record-by-record and row-by-row with the Target Accessibility Array (ITGC). Therefore, there is one record for every target which has at least one staging base accessible to it; and, each row of a record contains the performance data for the optimal path from the staging base to a LLTR exit on a path to the target.

The following sample SXPE table could have been generated by FLAPS either by entering the command "SHOW SXPE LEGNICA" or by entering the command "SHOW SXPE 135". If all of the SXPE records are desired, the command "SHOW SXPE ALL" can be entered.

WRSXPE -- THERE ARE 16 PATHS TO TARGET LEGNICA (135)

PATHS FOR STAGING BASE MILDENHA (3)

	LLTR EXIT		DISTANCE TO EXIT	PROB OF ARRIVAL AT EXIT
1	S088	(69)	607.93	0.9812
2	S089	(70)	596.60	0.9815
3	S092	(71)	608.64	0.9812
4	S102	(72)	614.23	0.9810
5	S120	(73)	665.81	0.9794
6	S133	(74)	690.98	0.9786
7	S134	(75)	692.32	0.9786
8	S135	(76)	667.62	0.9794
9	S136	(77)	630.13	0.9805
10	S137	(78)	654.74	0.9797
11	N150	(79)	544.67	0.9831
12	N151	(80)	539.24	0.9833
13	N152	(81)	536.11	0.9834
14	N153	(82)	593.83	0.9816
15	N154	(83)	585.71	0.9819
16	S155	(84)	596.23	0.9815

A.2.12 The Target Status (TGUS) Array

The Target Status Array TGUS is derived from the array ROUT by the weapons allocation command "AL". The weapons allocation procedure is to examine the targets in order of decreasing priority and to select for each the feasible sortie from the ROUT array with minimum expected aircraft losses. Feasible here means that the total number of aircraft allocated from any given staging base does not exceed the aircraft inventory for that base as defined in the staging base table STGB, that the aircraft have weapons available that can destroy the target, and that the aircraft can carry enough fuel to reach the target and return. The array TGUS consists of a one line summary of each of these selected sorties listed in order of decreasing target priority.

The contents of TGUS, which resembles an air tasking order (ATO), is examined using the command "SHOW TGUS". One sample is illustrated below.

TARGET	STAGING BASE	AIRCRAFT ALLOCATED	WEAPON TYPE	PD ACHIEVED	ROUTE PS	ROUTE DIST (NM)
SZPROTAW	SMARSTON	2 F111	GB10	0.998	0.16	1760.0
BAUTZEN	SOLLING	2 F-4	MK86	0.942	0.16	808.9
PANENSKY	SEMBACH	2 F-16	MK85	0.858	0.56	757.8
DOBRANY	BITBURG	2 F-4	MK82	0.983	0.22	732.6
ROTHENBG	SMARSTON	2 F111	GB10	0.998	0.53	1702.7
ZOLLSCHN	BITBURG	2 F-4	MK82	0.983	0.08	511.1
DESSAU	SOLLING	2 F-4	MK86	0.942	0.60	699.4
BRANDIS	BITBURG	2 F-4	MK82	0.983	0.11	808.3
MILOVICE	SEMBACH	4 F-16	MK85	0.980	0.21	826.0
CHKEUDHZ	SOLLING	2 F-4	MK86	0.942	0.05	648.2
LEGNICA	MILDENHA	2 F111	GB12	0.998	0.81	1859.3
PRESCHEN	SOLLING	2 F-4	MK86	0.942	0.19	830.8
KLECANY	SEMBACH	4 F-16	MK85	0.980	0.02	782.5
DREWITZ	BITBURG	2 F-4	MK82	0.983	0.84	704.7
PRESHYST	MILDENHA	2 F111	GB12	0.998	0.81	1763.1
KARLOVY	SEMBACH	2 F-16	MK85	0.858	0.00	570.8
CASLAV	BITBURG	2 F-4	MK82	0.983	0.05	799.2
LEIPZIG	--------	NO ALLOCATION	ACHIEVED	--------		
COCHSTED	SOLLING	2 F-4	MK86	0.942	0.98	605.4

ZATEC	SOLLING	2 F-4	MK86	0.942	0.56	812.5
PRAGUE		--------	NO ALLOCATION ACHIEVED		--------	
KOTHEN		--------	NO ALLOCATION ACHIEVED		--------	

As in the array ROUT, the probability of damage (PD) appearing in TGUS reflects only the effects of the selected weapon package on the target - not the probability of survival of the route (PS).

As the above illustration shows, there may be targets for which no suitable sortie can be found. Since weapons and aircraft are allocated to targets in order of decreasing target priority, this is particularly likely for the lower priority targets appearing at the bottom of the list.

A.2.13 THE THREE DIMENSIONAL STATESPACE (TH3D) ARRAY FILE

The three dimensional statespace array "TH3D" is an internal file that is used by the software and is not available for showing to the user. It is stored in an X,Y coordinate system. The array "TH3D" covers the operational area of interest for all the operational altitudes. The parameters for "TH3D" are stored in the parameter files "ALGP" and "GEOM". To load data into array "TH3D" you type the commands "ST AD" with the appropriate parameters as prompted. This causes the software to read the threat observability file and calculate the danger values which are then stored in array "TH3D". The array "TH3D" is used to load data into the array "STAT" for doing minimum lethality route calculations and threat suppression. The danger values in "TH3D" can be displayed by using the display commands described elsewhere in this document. The current default dimensions for this array are as shown below, where the number of flight directions = 8, the number of operational altitudes = 5, the number of longitude increments = 101, and the number of latitude increments = 114. These file dimensions are printed out when TH3D is opened by the initialization file ZCONTNU.DAT.

TH3D = 8 5 101 114

A.2.14 THE THREAT OBSERVABILITY (TOBS) ARRAY FILE

The threat observability file is an internal file that is used by the software, and is not available for showing by the user. The "TOBS" array contains the minimum observable altitude for each threat that has been masked by the FLAPS program. The data for each threat is stored in a subarray in the "TOBS" file using an X,Y coordinate system centered around the threat location. The data is stored in sixteen bit integers in units of meters. The subarray is intialized to 32764 meters before terrain masking. The "TOBS" file has as a header an information word, and two arrays. The information word gives the number of threats that have been masked and stored in the "TOBS" file. The first array consists of 8 character words that identify the threats that have been masked. And the second array consist of integer words that are pointers to the threat subarrays in the "TOBS" file. The "TOBS" file is dimensioned as shown below where 256000 is the available size of the "TOBS" file. The "TOBS" file is used in adding or deleting threats from the statespace, doing threat suppression, and doing route analysis. The following file dimensions are printed out when TOBS is opened by the initialization file ZCONTNU.DAT.

TOBS = 256000 1 1 1

A.2.15 THE LOW LEVEL TRANSIT ROUTE PERFORMANCE (TRPE) ARRAY

The Low Level Transit Route Performance Array gives the performance data for the optimal node sequences through the LLTR network. Performance, in this case, is the distance in nautical miles from an LLTR entry point to an LLTR exit point and the probability of arrival at the LLTR exit given one left from the LLTR entry point.

This array corresponds record-by-record and row-by-row with the Low Level Transit Route Accessibility (ITRC) Array. Therefore, there is one record for every LLTR entry point which has at least one LLTR exit point accessible to it; and, every row in a record contains the performances from the entry point to an accessible exit point. Because LLTR exits lie on the friendly side of the FEBA, there is no directionality included in the probability of arrival calculations. This means that the probability of arrival at the LLTR exit given one left from the LLTR entry is the same as the probability of arrival at the LLTR entry given that one left from the LLTR exit.

The following TRPE example could have been generated by FLAPS either by issuing the command "SHOW TRPE N001" or by issuing the command "SHOW TRPE 14". If all of the TRPE records had been desired to be shown, the proper command would have been "SHOW TRPE ALL".

WRTRPE -- THERE ARE 3 EXITS ACCESSIBLE TO LLTR ENTRY POINT N001 (14)

	LLTR EXIT		DISTANCE	PROB OF ARRIVAL
1	N150	(79)	173.60	0.9946
2	N151	(80)	168.17	0.9948
3	N152	(81)	165.04	0.9949

A.2.16 THE FLIGHT PLAN (SPED)

A flight plan may be generated from routes stored in the SPED table and displayed on the users terminal. This flight plan is in an easily interpreted form. It is recommended that users use this feature instead of the "SHOW SPED" command.

The form of the flight plan is as follows. A header is printed which gives the name of the sortie (the SPED table record ID), the ID and index of the staging base and target, the total probability of survival, the probability of kill due to threats, the flight distance (in nautical miles), the take off time (in decimal minutes), the time on target (in decimal minutes), and the number of waypoints. These are all labeled. Refer to Section 3.1.10 for a description of the SPED table. The actual flight plan is shown as a list of waypoints. Each waypoint consists of time (in decimal minutes), latitude and longitude (in degrees, minutes and seconds), altitude (in feet), heading (in decimal degrees from north), and the node ID. A node ID will appear at the first and last waypoint (the staging base), at the target, and at all of the LLTR points. Simple turn points do not have a node ID listed.

To show a flight plan, the user should type "SHOW PLAN". FLAPS will then prompt the user for a SPED record ID or a record number. The user may enter either, whichever is more convenient. The following table was generated by FLAPS using the SHOW PLAN command for a SPED record with ID BITB.CASL.01, and record number 6. The plan could have been generated by entering either:

SHOW PLAN BITB.CASL.01

or

SHOW PLAN 6

WRPLAN - FLIGHT PLAN FOR SORTIE: BITB.CASL.01

STAGING BASE BITBURG (5) TO TARGET CASLAV (134)
PROB OF SURVIVAL: 0.0482 THREAT PK: 0.9518
FLIGHT DISTANCE: 799.22 NM
TAKE OFF TIME: 0.0000 TIME ON TARGET: 41.3191 OF WAYPOINTS: 34

TIME (MIN)	LATITUDE (DMS)	LONGITUDE (DMS)	ALTITUDE (FEET)	HEADING (DEG)	NODE ID
0.000	49 58 00	6 31 59	393.70	132.86	BITBURG
6.212	49 17 17	7 39 15	393.70	105.47	S079
8.163	49 12 17	8 06 54	393.70	113.83	S080
10.722	49 02 20	8 41 14	393.70	100.43	S097
13.871	48 56 52	9 26 32	393.70	86.12	S098
16.694	48 58 42	10 07 44	393.70	85.53	S099
19.680	49 00 56	10 51 17	393.70	56.51	S100
22.673	49 16 45	11 27 57	393.70	52.05	S101
25.452	49 33 08	12 00 19	393.70	84.29	S102
28.454	49 35 60	12 44 33	393.70	45.21	
28.809	49 38 24	12 48 17	393.70	90.00	
29.565	49 38 24	12 59 29	393.70	45.17	
30.274	49 43 12	13 06 57	393.70	91.54	
39.585	49 40 48	15 25 06	393.70	0.00	
41.085	49 55 12	15 25 06	393.70	323.14	
41.319	49 57 00	15 22 60	393.70	229.92	CASLAV
42.774	49 47 60	15 06 26	393.70	206.70	
43.333	49 43 12	15 02 42	393.70	270.00	
46.099	49 43 12	14 21 37	393.70	225.40	
49.653	49 19 12	13 44 17	393.70	270.00	
50.413	49 19 12	13 33 05	393.70	225.42	
50.769	49 16 48	13 29 21	393.70	180.00	
51.019	49 14 24	13 29 21	393.70	225.47	
51.376	49 12 00	13 25 37	393.70	270.00	
53.663	49 12 00	12 52 01	393.70	302 21	
57.801	49 33 08	12 00 19	393.70	232.20	S102
60.580	49 16 45	11 27 57	393.70	236.65	S101
63.572	49 00 56	10 51 17	393.70	265.54	S100
66.558	48 58 42	10 07 44	393.70	266.12	S099
69.382	48 56 52	9 26 32	393.70	280.45	S098
72.531	49 02 20	8 41 14	393.70	293.90	S097
75.090	49 12 17	8 06 54	393.70	285.49	S080
77.041	49 17 17	7 39 15	393.70	313.26	S079
83.253	49 58 00	6 31 59	393.70	313.26	BITBURG

A.2.17 THE BYTE (BYTE) ARRAY FILE

The byte array file is an internal file that is used by the software and is not available for showing to the user. It contains byte packed DTED data that is in an SCT format. To change the area of operation requires formatting a new data file. This file is used during the terrain masking process. This file has a header shown below that is described for the current scenario as, minimum longitude = 11 degrees east, minimum latitude = 48 degrees north, maximum longitude = 20 degrees east, maximum latitude = 54 degrees north. The following file dimensions are printed out when BYTE is opened by the initialization file ZCONTNU.DAT.

```
LUNTER,MXRCTR= 0 0

IHDR= 11.  48.  20.  54.  200 240 8 16
```

A stand alone program called FMBYTD has been developed by SCT to create byte packed DTED terrain data files.

APPENDIX B

FLAPS GLOSSARY

AAA---------- Antiaircraft Artillery
AAFCE---------- Allied Air Forces Central Europe
ACCESSIBLE NODE-------- A node which can be reached directly from another node.
ACCESSIBLE NODES BOX--- A rectangular area containing all of the nodes which can be reached from a given node. Used by the DPA when *building arcs*.
ACO---------- Airspace Coordination Order
AGL---------- Altitude Above Ground Level
ALTG---------- An array containing the optimal altitude of an aircraft above the ground.
ALTS---------- An array containing the optimal altitude of an aircraft above sea level.
ARC---------- Path between two nodes
ATAF---------- Allied Tactical Air Forces
ATM---------- Air Tasking Messages
ATO---------- Air Tasking Order
ATOC---------- Allied Tactical Operations Center
CL3D---------- The Three Dimensional Clobber array
COMPASS CALL---------- Airborne non-lethal electronic combat system
COOKIE-CUTTER TEMPLATE- A circular uniform threat lethality model.
CONTOUR MAP(s)--------- Graphic displays of terrain heights; flight altitudes; roughness; slope; or danger. Lines are plotted to show regions of equal value at set increments.
CORRIDOR---------- A high probability-of-survival route segment through which sorties will be flown; created by applying threat suppression assets.
DANGER---------- A quantitative representation of the threat to a penetrating aircraft at a location. Mathematically, the negative

	of the natural logarithm of the combined probability of survival per second.
DBMS----------	Data Base Managment System
DCL----------	DEC Command Language
DIALOG AREA----------	The part of the terminal screen where the user's commands are entered and data and messages from FLAPS are displayed.
DMA----------	Defense Mapping Agency
DOO----------	Daily Operations Order
DPA----------	Dynamic Programming Algorithm
DTED----------	Digital Terrain Elevation Data
EC----------	Electronic Combat
EIFEL----------	Multi-national automated tactical command, contraol, and information system.
ENTRY LLTR NODE--------	The first LLTR node an aircraft will encounter upon leaving a staging base.
ENVELOPE----------	A region defining the maximum extent of a threat.
ESAMS----------	Air Force approved computer program for generating radar mission templates.
EVENT----------	The numeration of action points along a route, eg. turn point, or a change in threat status.
EW----------	Electronic Warfare
EW/GCI----------	Early Warning/Ground Control Intercept Radar
EXIT LLTR NODE---------	The last LLTR node an aircraft will pass before crossing the FEBA.
FEBA----------	Forward Edge of Battle Area
FLAPS----------	Force Level Automated Planning System
GCI----------	Ground Control Intercept Area
ID----------	Identification, in FLAPS, ID usually refers to the alphameric name of some data object.
INACTIVE LLTR NODE-----	An LLTR node which is not available for use during the current planning cycle.
INTERMEDIATE LLTR NODE-	Any LLTR node which is available for use during the current planning cycle, but which cannot be reached directly from a staging base and cannot directly access the FEBA.
LEG----------	A segment of a route between consecutive turn points.
LLTR----------	Low Level Transit Route
LOCE----------	Limited Operational Capability Europe
MICROVAX II----------	A small 32 bit DEC micro-computer
NATO----------	North Atlantic Treaty Organization
NODE----------	Significant route points, eg. staging bases, LLTR points, and targets.
NODE INDEX----------	A unique number corresponding to every active staging base, LLTR point, or target.
OCA----------	Offensive Counter Air
PA----------	Probability of Arrival for penetrating aircraft

PD---------- Probability of Destruction of target

PEN-AIDS---------- Penetration analysis Aids system for tactical air forces.

PK---------- Probability of Kill of penetrating aircraft

PS---------- Probability of Survival of penetrating aircraft

PRIMARY COMMAND-------- A FLAPS command designed to be used by a mission planner.

RCS---------- Radar Cross Section

ROZ---------- Restricted Operating Zone

SAM---------- Surface-to-Air Missile System

SCALAR---------- A data structure containing only a single element.

SCENARIO SPACE--------- The entire geographical region under consideration during a FLAPS session.

SCL---------- Standard Conventional Load

SCT---------- Systems Control Technology, Inc.

SECONDARY COMMAND------ A FLAPS command designed to be used by program developers.

STALE DATA---------- Data generated using input partameters or data bases that have since been modified, eg. routes generated using the statespace before it was modified.

STAT---------- The array containing the current statespace.

STATESPACE---------- Eight-directional grid collapsed from two or 3-dimensional dangers. Used to determine cost of travel from one cell to another.

STATESPACE CELL-------- A geographic and altitudinal region in which the probability of surviving threats has been quantified.

STOCHASTIC THREAT------ A mobile threat whose location is only approximately known with time.

SURVIAC---------- The Survivability/Vulnerability Information Analysis Center

SWITCH---------- A data construct which provides the FLAPS program with information about how it is currently configured.

TAC---------- Tactical Air Command

TAC ZINGER---------- Computer program simulating Soviet defensive sights versus penetration aircraft.

TAF---------- Tactical Air Forces

TAFIG---------- Tactical Air Force Inter-operability Group

TEKTRONIX 4115-B ------ The color graphics display for FLAPS.

TERRAIN FOLLOWING------ Flight path that maintains a constant terrain clearance altitude.

TERRAIN MASKING-------- Using the terrain to minimize exposure to threats.

TF---------- Terrain Following

THREAT MODEL---------- A data structure which contains generic information about a specific type of threat.

TH2D---------- An array containing the Two Dimensional Threat environment data.

TH3D---------- An array containing the Three Dimensional Threat environment data.

TOT---------- Time on Target

TREE---------- Optimum sequence of LLTR nodes from each LLTR entry point to all accessible LLTR nodes.

USAFE---------- United States Air Forces Europe

VAX 11/750 ---------- A 32 bit DEC mini-computer upon which will run the FLAPS program.

VECTOR---------- A data structure which contains many elements.

WAYPOINT---------- A point on a route where one or more of the flight parameters change, eg. heading or altitude.

WILD WEASEL---------- Aircraft configured with airborne lethal defense suppression weapons.

WFZ---------- Weapons Free Zone

END
FILMED
4-86
DTIC